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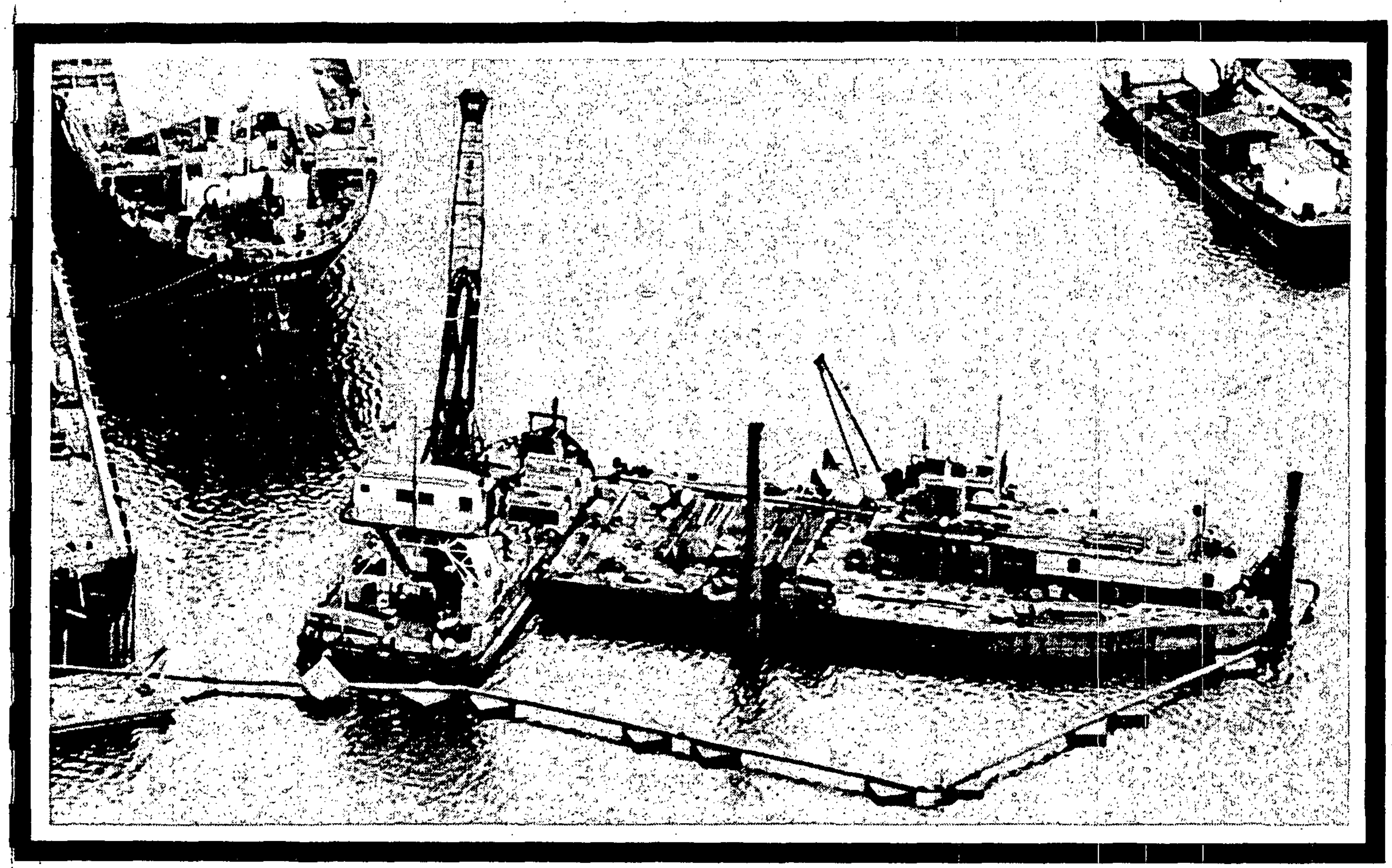
MONITORING OF TRACE CONSTITUENTS DURING PCB RECOVERY DREDGING OPERATIONS

DUWAMISH WATERWAY



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ABSTRACT

This report describes the monitoring program conducted after a spill of 255 gallons of transformer fluid, Aroclor 1242, occurred in the Duwamish River in Seattle, Washington. A detailed evaluation is presented of data acquired prior to, during, and after recovery operations. An initial recovery effort conducted by EPA resulted in a 30 percent removal of the PCB. The Department of Defense, acting through the Corps of Engineers, removed the remaining Aroclor using a Pneuma dredge. This removal operation increased the total PCB recovered to approximately 92 percent.

The second recovery effort was conducted without significant redistribution of toxic materials and bacteria associated with the dredged sediments. No appreciable amount of PCB returned from the disposal ponds to the river because of the design of the land disposal area and of the use of a filtration-adsorption treatment unit. Water, which drained from the dredged spoils in the disposal pond, contained some Mn, N-NH_3, N-TKN, oil and grease, and total coliform, but only traces of Cd, Fe, Zn and total P. Apparently most of the pollutants and bacteria were associated with or scavenged by particulate matter and settled in the disposal ponds. Only small concentrations of toxic materials, nutrients, and suspended solids were observed to be released into the overlying river water during dredging operations.

The release of pollutants from sediments during dredging could be only partially predicted by use of the elutriate test and evaluation of the interstitial water. The elutriate test was valid for most metals, nutrients, and oil and grease. However, both tests failed to preduct the amount of PCB released.

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Part I. INTRODUCTION

(A) BACKGROUND

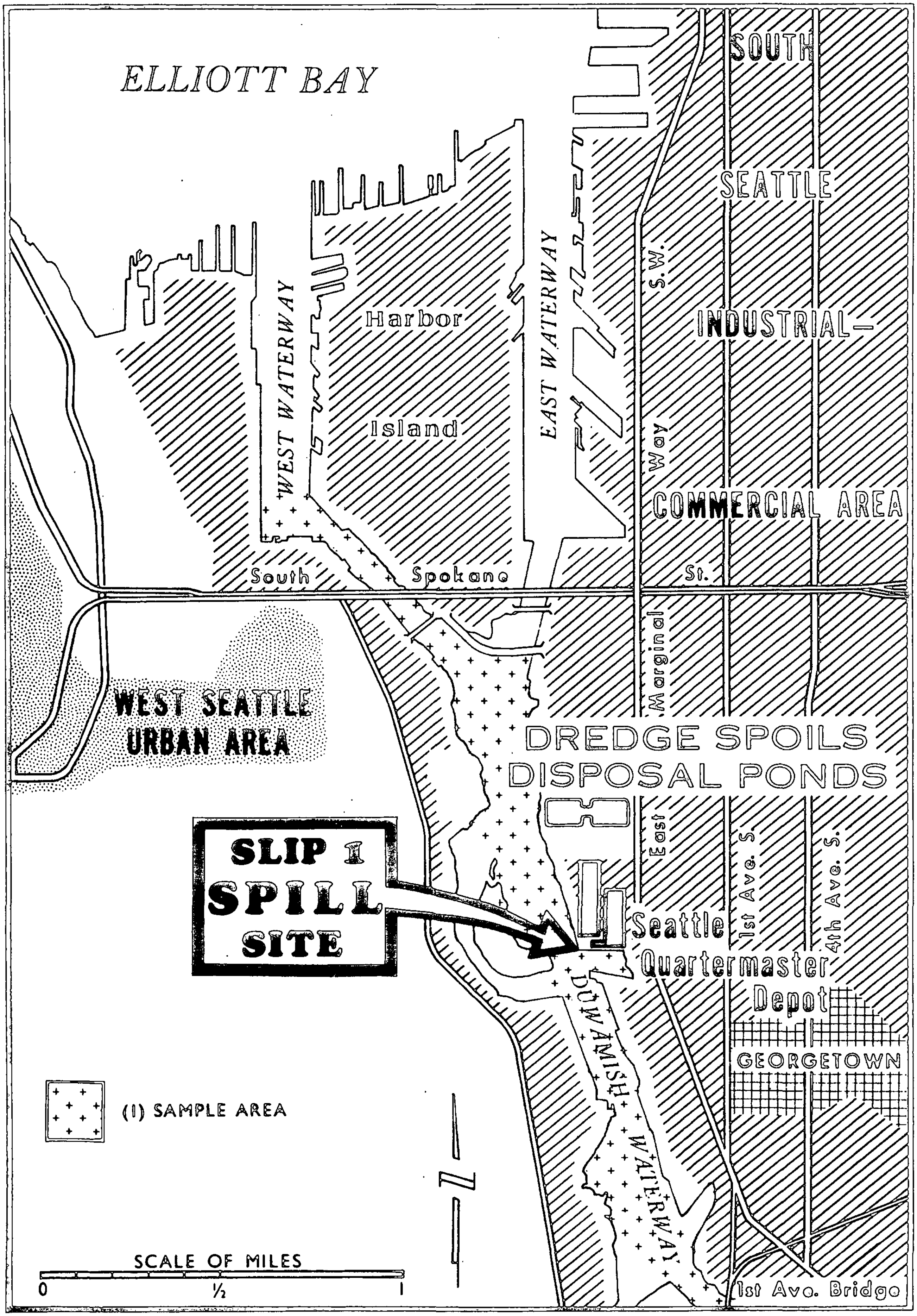
On September 13, 1974, an electric transformer destined for arctic service was dropped and broken on the north pier of Slip 1 of the Duwamish River, Seattle, Washington (Figure 1). As a result, PCB transformer fluid, Aroclor 1242, was discharged onto the pier and into the water. After becoming aware of the type and quantity of fluid spilled, EPA acted to determine the extent of pollution. Once determined feasible, clean up of the fluid was attempted using several hand dredges (1).

Results from EPA Region X Laboratory's monitoring of this clean up operation indicated only eighty of an estimated 255 gallons of PCB were recovered and the remaining fluid had begun to spread throughout the slip and into the river channel (2). Recognizing the seriousness of this problem, DOD and the Army Corps of Engineers conducted a second recovery operation to remove the remaining PCB using a Pneuma Model 600 dredge.

The Corps of Engineers piped the contaminated sediments to a disposal site prepared on land 2,000 feet north of the slip. All dredge spoil water was treated with Nalco #7134 flocculent, passed through two disposal ponds and filtered through both a particle filter containing Filterite #264MSO and EPA's activated carbon treatment unit.

(B) OBJECTIVE

The primary purpose of the Region X Laboratory's involvement in the second clean up was to assist the Army Corps of Engineers' Seattle district by monitoring the Corps recovery of the remaining PCB. A monitoring scheme was designed to evaluate the hydraulic dredging of PCB polluted sediments in Slip 1 to determine the amount of PCB removed, the extent of PCB translocation and the amount of PCB remaining on the river bottom after dredging. Also, an attempt was made to evaluate the usefulness of predictive methods such as the "Standard Elutriate Test" and "Interstitial Water Evaluation" as important procedures for determining the impact of a dredging operation on dredge and disposal site water quality.



PCB SPILL LOCATION

SEPT. 13, 1974

FIGURE 1

Both dredge and disposal sites were monitored extensively during the dredge operation for PCB's, metals, nutrients and other potentially harmful materials, including microorganisms of public health significance. Also, a pre-dredge and post-dredge pollutant monitoring program with emphasis on predictive testing and subsequent evaluation was carried out.

EPA Region X Laboratory's objectives for monitoring the Corps PCB clean up operation at Slip 1 were:

(1) Map and assess the amount of PCB on the river bottom prior to the clean-up effort.

(2) Estimate the amount of PCB removed from the river bottom as a result of the Corps dredging operation.

(3) Estimate the extent of PCB pollution remaining on the river bottom after dredging.

(4) Determine the extent of PCB translocation resulting from the recovery operation.

(5) Determine amounts of deleterious materials released into the water column at the dredge site as a result of the clean-up operation.

(6) Predict and compare quantities of pollutants returning to the river from dredge spoil disposal ponds.

(C) SCOPE

Phase I: Pre-Dredge Monitoring

The objectives necessitated a comprehensive monitoring program that allowed the observer to detect environmental disturbances directly attributable to the dredging operation. A pre-dredge evaluation of Slip 1 sediments was made to determine PCB, trace metals, nutrients, oil and grease, water quality, and microbiological parameters. Determination of PCB in surface sediments was performed to map the extent of contamination prior to the Corps dredging operation. Data obtained from PCB and other measurements afforded an opportunity to assess the effects of sediment disturbances during a hydraulic dredging operation. Predictive tests, "Standard Elutriate Test" and "Interstitial Water Evaluation", were conducted to determine the potential release of pollutants to the water column.

A river water evaluation program was initiated by monitoring background water at the dredge site for future reference to any plume created by the dredging operation. Composite samples of suspended particulate matter (SPM) and whole water were collected at two depths, surface and eight meters, over desired time intervals and analyzed for PCB's. Whole water composite samples were monitored for trace metals, nutrients, oil and grease and other water quality parameters. Collection of samples from surface and eight meters was desirable since the Duwamish is a salt wedge estuary possessing both fresh surface and deep salt water layers usually separated by a strong pycnocline.

Phase II: Dredge Monitoring

Disposal pond influent and effluent were evaluated by analyzing several whole water composites while the dredging operation was in progress. At the same time, sediments from dredged area were analyzed for Aroclor 1242 to determine the success of the PCB removal operation. The effect of dredging on river water near the dredge site was established by monitoring SPM and whole water samples.

Phase III: Post-Dredge Monitoring

A post-dredge survey of remaining Slip 1 sediments, consisting of analysis of bulk sediments and interstitial water, was necessary to determine if pollutants such as PCB remained on the river bottom in substantial quantities and if translocation of Aroclor 1242 occurred during the dredging operation. Also, an attempt was made to determine if water quality comparable to pre-dredge conditions existed at Slip 1 after completion of dredging activities and to establish the success of PCB removal from Slip 1.

Part II. CONCLUSIONS

The recovery effort resulted in the removal of most of the spilled Aroclor from Slip 1 without evidence of significant PCB translocation. Two independent methods were used to calculate the amount of PCB recovered. The first utilized an estimate of the amount of PCB contaminated dredged materials removed from designated areas within the spill site. The second method was based on the concentration of PCB found in the dredged materials actually deposited in the disposal pond. Estimates of the amount of PCB recovered using these methods are 220 and 250 gallons, respectively. The average value of PCB removed 235 gallons, represents a 92% recovery. It follows that approximately 20 of the 255 gallons of PCB spilled are assumed to be on the river bottom or unaccounted for at this time. Substantially reduced levels of PCB were detected in the impact area and only trace amounts of the substance were found to be present in the remaining portion of the slip. The river channel remained free of the spilled Aroclor indicating that less than a detectable amount of the pollutant was transported out of the spill site during the final clean-up operation.

In comparison, analysis of survey data obtained during the first three month period after the spill indicates that some translocation of Aroclor 1242 into the river channel occurred during the first clean-up operation. Apparently, divers with hand held dredges disturbed the pollutant, allowing transport of the material to occur. This situation was further aggravated by natural dispersal forces acting on the transformer oil which laid unprotected on the river bottom.

Subsequent surveys during the months that followed demonstrated that normal river sedimentation tended to cover the contaminated sediments and that the spread of PCB occurred mainly toward the back portion of the slip. Also, the force of a "20 year flood" experienced in the Duwamish Estuary during the winter of 1976 either diluted or scoured the contaminated river channel sediments such that no detectable amount of PCB remained in the channel. However, no significant changes attributable to the flood were noted in sediment concentrations within the slip proper. The continual migration of Aroclor 1242 towards the back of the slip appears to have been influenced by docking and embarking activities of ships in the area and other factors such as tidal action.

A slow but persistent movement of transformer fluid could have eventually contaminated the entire slip and polluted much of the Duwamish River if the spilled PCB was allowed to remain on the slip bottom. Successful completion of the removal operation terminated that migration and dramatically lessened possible serious long term effects of the spill.

Levels of several pollutants in dredge spoil return water and dredge site water remained near background during the dredging operation. [redacted] on of these observations with predictive tests used to estimate the amount of a pollutant released during dredging is good. Considering the degree of accuracy possible for this type of estimate, the "Standard Elutriate Test" appears to be valid for most metals, nutrients and oil and grease. However, "interstitial water evaluation" of sediments employed in this study met with only limited success. Both tests failed to accurately predict the amount of PCB released.

As our results indicate, a large number of bacteria of public health significance can be removed from both sediments and interstitial waters by a properly monitored hydraulic dredging operation. In most instances, a significant reduction was obtained in total coliform (TC), fecal coliform (FC), and clostridium perfringen (C. perfringens) populations from all sampling locations surrounding the impacted area. The removal of C. perfringens was of particular importance because of its known pathogenicity and close association with organic material originating from human fecal waste. The removal of sediment bound bacteria by passage through disposal ponds 1 and 2 was effective for the elimination of FC, fecal streptococci (FS) and C. perfringens but not TC and organisms enumerated by the 20° C plate count. The reason for this disparity is still unclear, but may relate to the lack of aggregate formation or adsorption to sediment particulates. Nevertheless, it still appears that large portions of the enteric bacterial population can be effectively removed from bottom sediments and eliminated by proper land disposal. The fate or survivance of these bacteria on land, however, is quite variable and dependent upon a multitude of environmental and nutritional factors.

Part III. EXPERIMENTAL

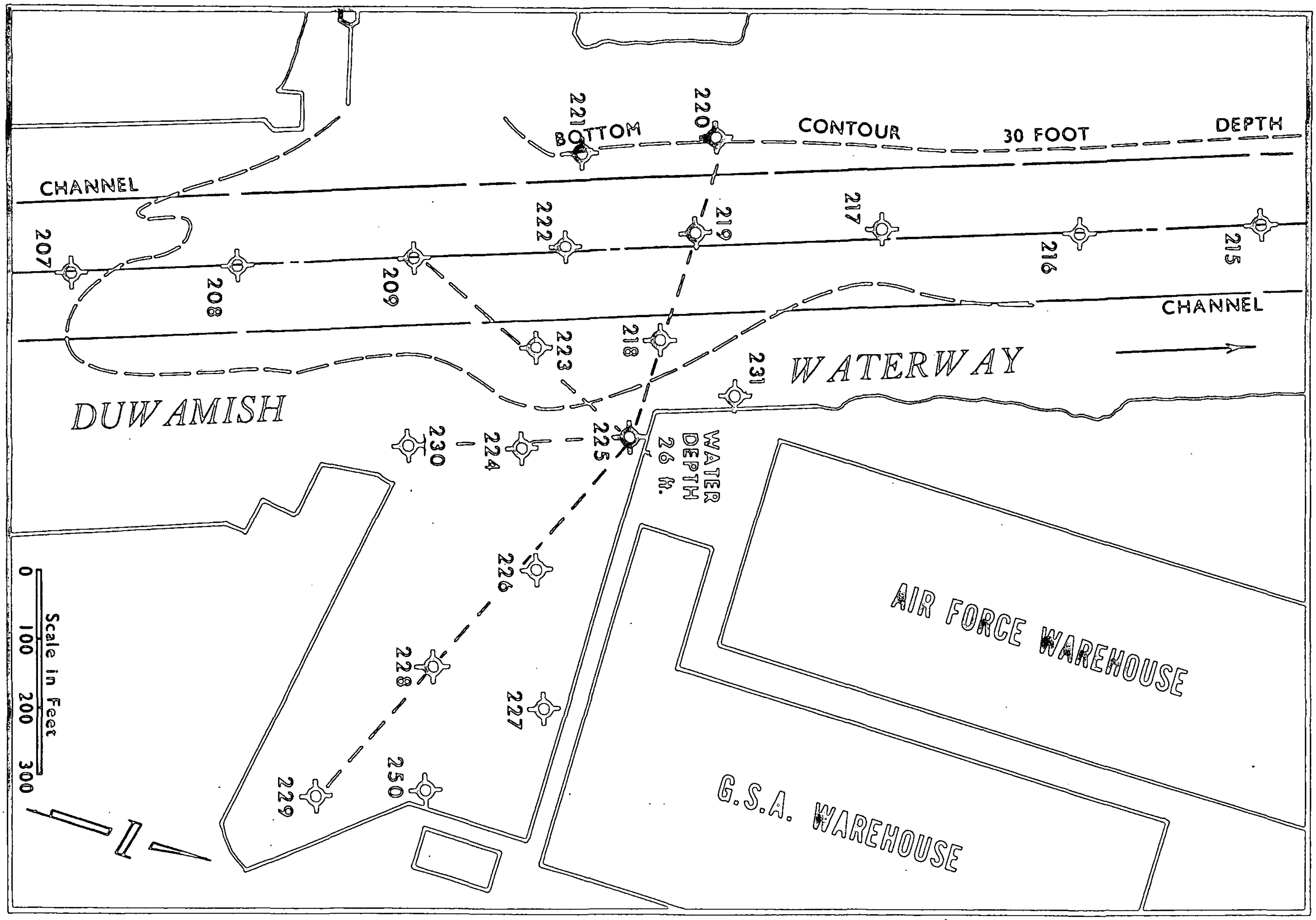
(A) SAMPLING

(1) Slip 1 Sediments

River bottom sediments were sampled over a two and one half mile reach of the Duwamish River shown in Figure 1. The sampling area extended north from the First Avenue Street Bridge to the south portion of the West Waterway. Sample station locations in and around Slip 1 (shown in Figure 2) included four transects centered at station 225 (location of the spill) proceeding out to stations 229, 230, 209, 220 and additional stations which were used to provide more complete coverage of the area. All other stations were taken at mid-channel with sample intervals ranging from 250 feet within 2,000 feet of the spill site to 1,000 feet beyond this point. Surveys of river bottom sediments were made over a two year period (see Table 1). Surface sediment samples were taken using a Van Veen sampler. The top five centimeter section of the sample was carefully removed from the sampler, placed in a pretreated 8 oz. jar, capped with a teflon-lined lid and stored at 4^{0} C until analysis was performed. This method was used to detect translocation of PCB associated with movement of fines or flocculent sediment. Core samples were also taken on at least two occasions using a Phleger coring device in order to define the extent of vertical migration of the pollutant.

Originally, composite samples were obtained from six areas in Slip 1 thought to be dissimilar in chemical composition using a Van Veen sampler and a Phleger coring device. Sample stations used to make up the composites are shown in Figure 3. The samples were mixed, capped, held at 4^{0} C and taken to the laboratory for evaluation using the Standard Elutriate Test, interstitial water evaluation and bulk sediment analysis. Since areas three and four were later found to be similar in chemical composition, they were combined.

Several sets of Slip 1 sediments were analyzed during the second removal effort to determine the degree of success of the clean up operation. Dredged areas, thought to be free of spilled Aroclor, were sampled using a Van Veen sampler while the removal effort was in progress. A representative portion of each grab sample was removed and analysis was initiated within one hour after collection. Sampling points used to check dredging efficiency are shown in Figure 4.



STATION NUMBERS AT SLIP 1

FIGURE 2

TABLE 1

RESULTS OF PCB AND METALS ANALYSIS

1242 1254

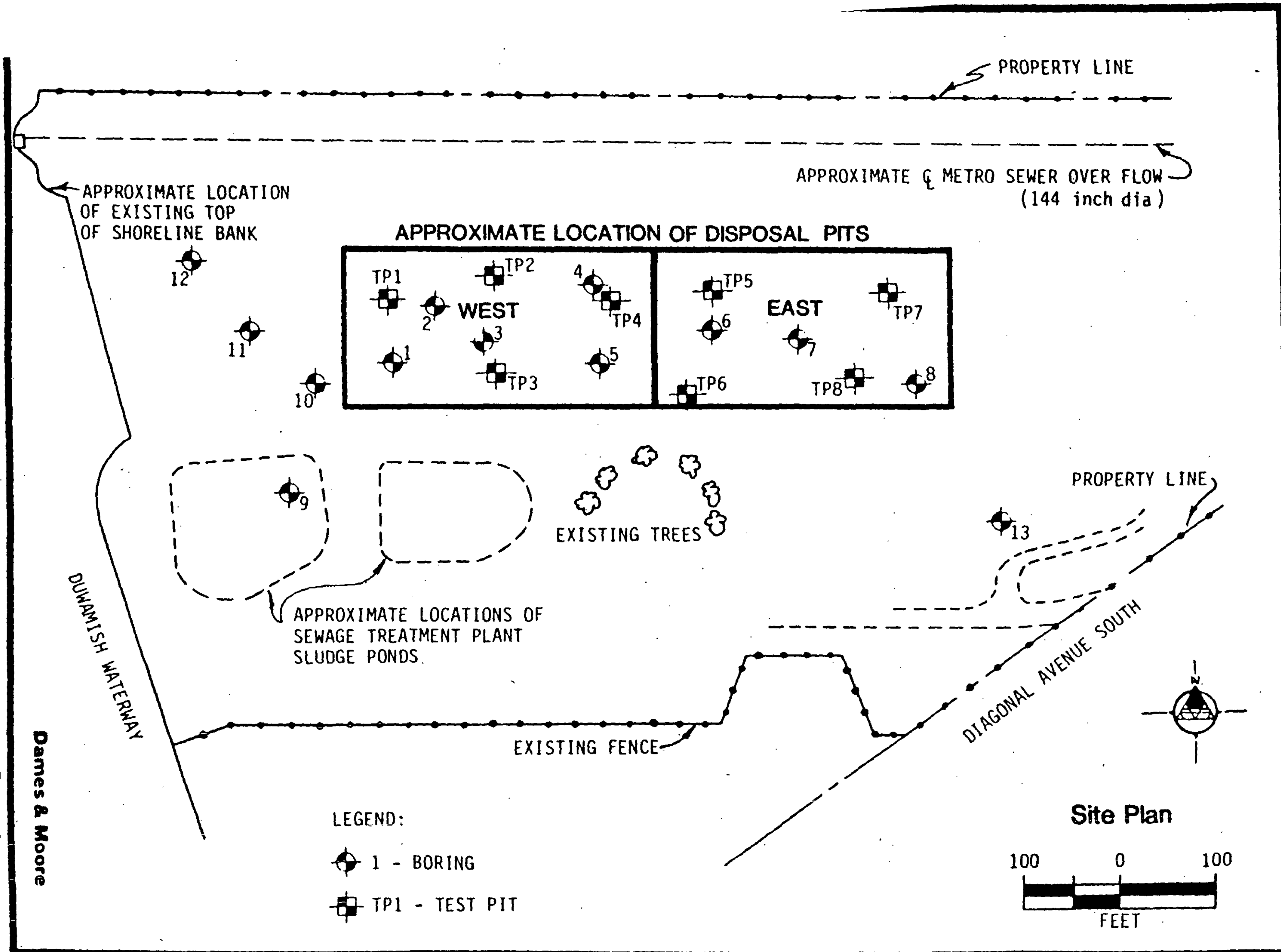
Sample Number	Depth (feet)	PCB (ppm)	Arsenic (ppm)	Cadmium (ppm)	Chromium (ppm)	Lead (ppm)	Mercury (ppm)	Zinc (ppm)	Total Solids (%)
Test Pits									
TP1-2	9-1/2	0.432	6.3	0.63	17.	16.	<0.02	49.	82.6
TP2-2	10	1.19	12.	0.54	13.	14	<0.02	50.	86.5
TP3-2	10	0.803	9.	0.54	16.	17.	0.04	46.	84.1
TP4-1	8	1.72	5.2	0.64	27.	33.	0.19	63.	81.2
TP5-1	5	0.225	4.4	0.58	14.	16.	<0.02	34.	83.0
TP6-1	5-1/2	2.11	4.2	0.69	16.	18.	<0.02	36.	83.9
Borings									
B1-2	6	2.06	8.	1.4	39.	41.	0.24	86.	71.4
B1-4	11	4.89	19.	15.	64.	240.	0.17	2,500.	59.1
B1-8	21	0.013	7.	0.31	10.	4.	<0.02	22.	72.6
B2-1	2-/12	2.73	6.	1.4	39.	72.	0.13	91.	80.1
B2-6	16	0.169	1.5	0.22	3.9	4.	0.06	19.	7.0
B3-2	6	2.29	5.2	1.4	42.	88.	0.15	110.	73.9
B3-7	19	0.171	4.7	0.32	11.	6.	0.15	24.	58.9
B4-3	9	0.512	9.	0.85	24.	39.	0.07	88.	73.7
B4-8	21	<0.010	4.1	0.37	11.	4.	0.04	24.	73.4
B5-2	6	2.60	7.	2.0	85.	45.	0.23	140.	69.7
B5-6	16	4.27	10.	3.1	150.	130.	0.32	320.	50.5
B6-7	19	1.71	4.9	2.0	62.	140.	0.13	140.	55.3
B7-1	2-1/2	0.709	4.8	1.4	13.	14.	<0.02	43.	88.8
B7-5	14	1.21	9.	1.7	25.	350.	0.11	130.	79.3
B8-5	14-/12	1.13	5.5	0.85	19.	57.	0.10	54.	77.9
B8-9	24	<0.01	6.1	0.32	11.	6.	<0.02	25.	73.5
B9-6	15-1/2	0.102	8.2	0.47	11.	6.	0.05	28.	69.5
B10-3	9	5.91	17.	3.3	380.	240.	0.40	280.	69.7
B10-6	16	0.443	7.2	0.46	11.	6.	<0.02	25.	67.4
B10-9	24	<0.01	6.0	0.35	10.	6.	<0.02	23.	73.6
B11-7	19	0.661	8.0	0.53	12.	11.	0.03	35.	73.5
B11-10	26-/12	<0.01	3.4	0.27	7.5	3.	0.05	21.	81.9
B12-9	15-/12	<0.01	1.7	0.19	5.9	2.	0.04	14.	81.7
B13-8	24	<0.01	7.2	0.39	12.	7.	0.05	28.	71.9

TABLE II

RESULTS OF CHEMICAL ANALYSES ON SOIL SAMPLES FROM BORINGS 84-1 TO 84-11

Location	Depth (feet)	PCB[1] (µg/g[ppm])	Aroclor	As	Cd	Cr	Pb	Hg	Zn	% Solids
				(mg/kg[ppm])						
84-1	1.5-3	--		8.5	0.25	19	7.8	0.12	53	86
84-1	4-6	--		15	4.6	50	170	0.25	280	76
84-2	1.5-3	7.2	1242	7.5	0.60	100	11	0.55	83	73
		3.2	1254							
84-2	1.5-3	9.9	1242	7.8	0.55	120	140	0.81	58	72
	(dupl.)	4.1	1254							
84-3	4.5-7	--		6.0	0.55	43	29	0.20	75	85
84-3	9-10.5	--		6.8	0.32	19	17	0.20	71	83
84-3	12-14	6.7	1242	8.4	0.52	34	22	0.14	100	69
84-4	1-3	3.2	1254	6.0	0.081	21	18	0.14	27	80
84-5	1-2.5	--		5.2	0.35	17	9.3	<0.1	52	86
84-6	4-5.5	--		6.5	0.38	9.8	2.9	<0.1	25	78
84-7	1.5-3	--		4.1	0.10	11	9.7	<0.1	19	91
84-8	1-2.5	--		4.8	0.31	13	5.5	<0.1	31	85
84-9	1.5-3	--		5.0	0.40	17	5.0	0.12	39	88
84-10	1.5-3	--		4.5	0.074	6.1	1.3	<0.1	17	73
84-10	4-6	--		4.2	3.1	28	41	0.28	110	87
84-11	1-2	--		3.8	0.11	6.2	3.5	<0.1	16	82
84-11	3.5-5	--		3.9	0.070	7.3	1.9	<0.1	24	78
Spike[2] (QA:recovery)		11 (76%)	1254	124%	99%	100%	96%	90%	94%	

Note: (1) Where -- occurs in table, the PCB concentration is less than the detection limit of 1 part per million (ppm) (mg/kg).
(2) The spike was prepared at the lab for a quality control check.
(3) Duplicate sample tested for quality control check.

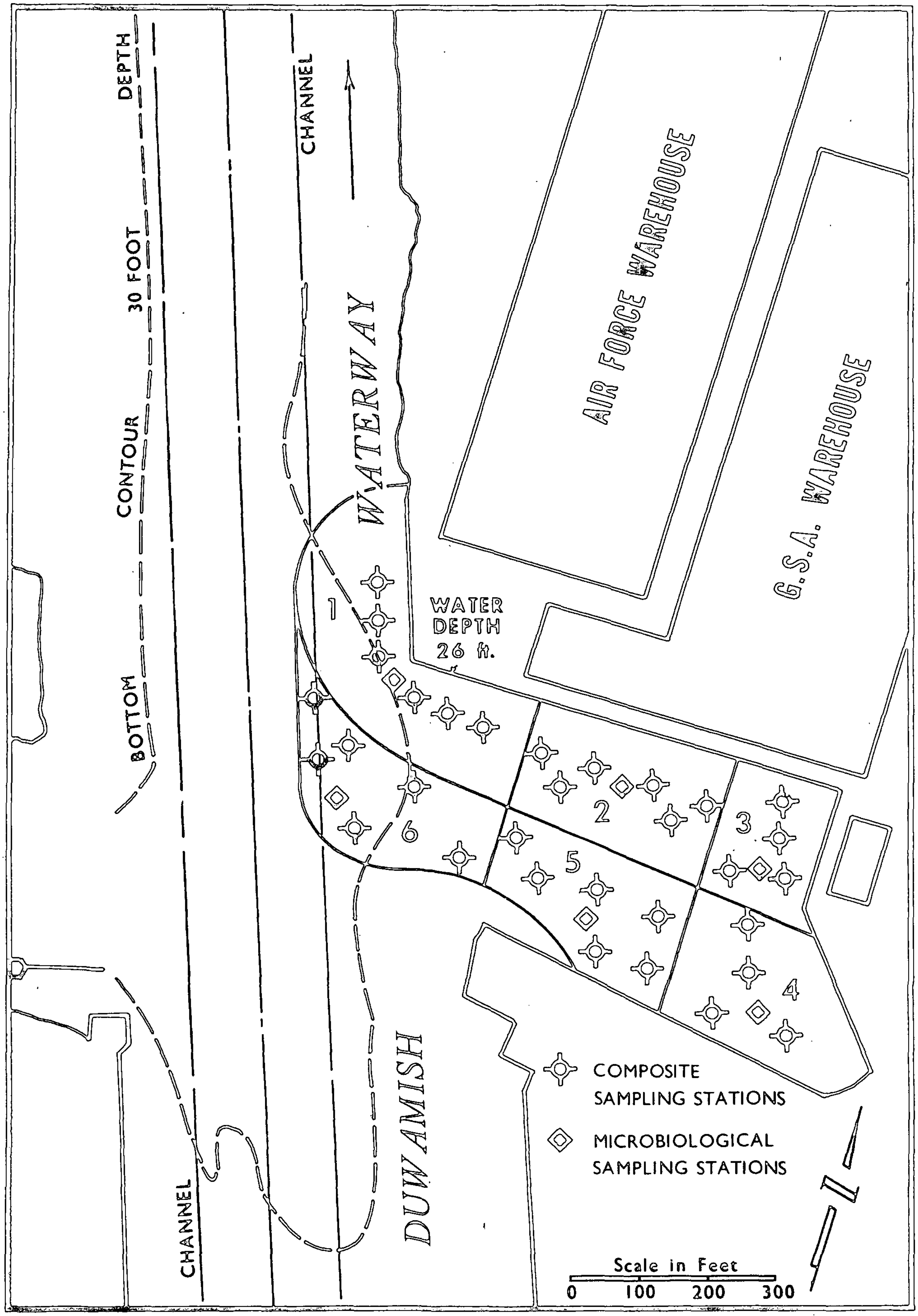


Dames & Moore

Plate 2

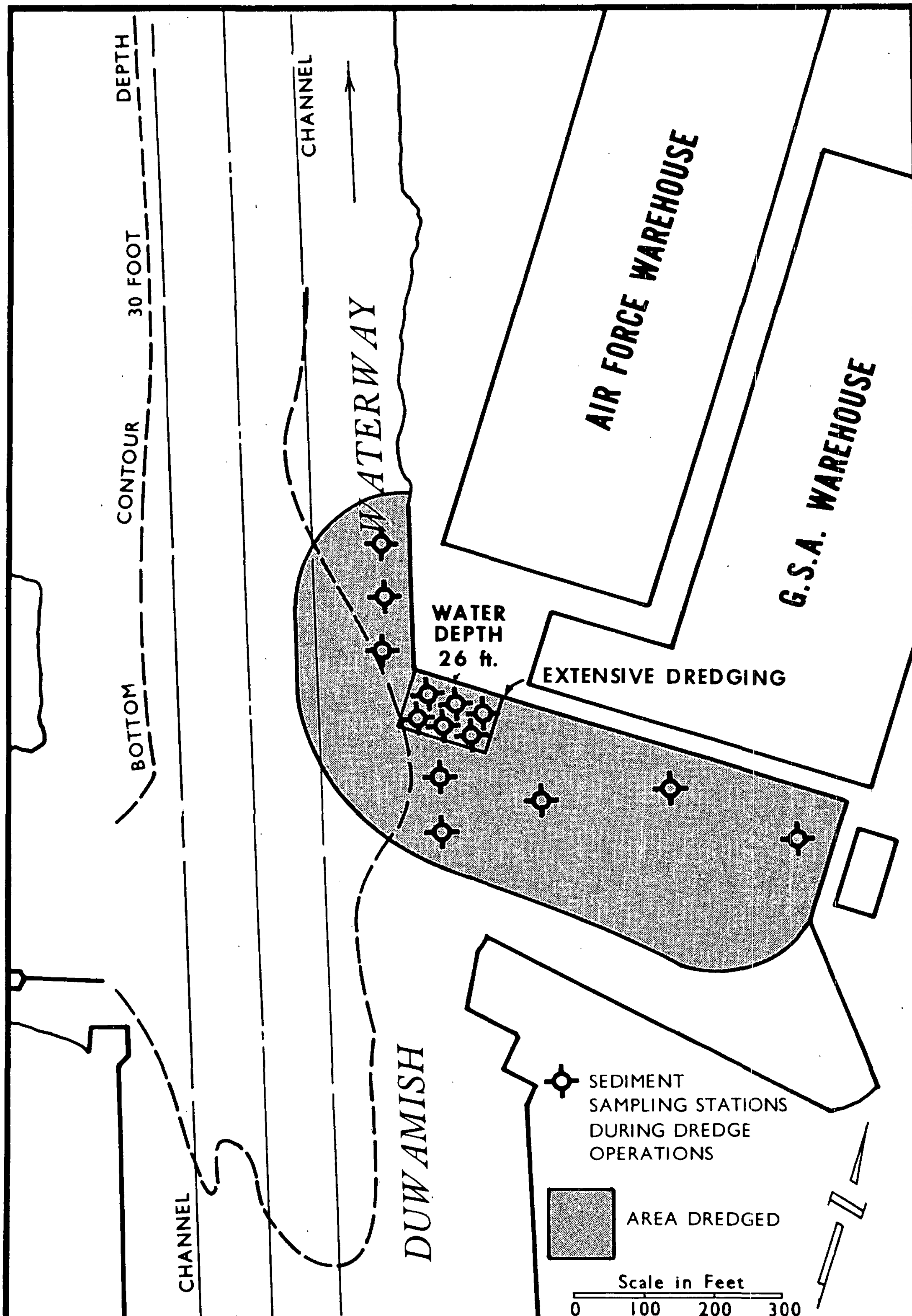
Table 1. FREQUENCY OF RIVER SURVEYS FOR PCB IN DUWAMISH SEDIMENTS

Survey Number	Extent of Survey	Date	Elapsed Time From Date of Spill Sept. 13, 1974
1	Full	Sept. 18, 1974	5 days
2	Partial	Sept. 25, 1974	12 days
3	Partial	Oct. 18, 1974	35 days
4	Full	Nov. 4, 1974	52 days
5	Partial	Feb. 20, 1975	159 days
6	Full	June 2-4, 1975	263 days
7	Partial	Aug. 18, 1975	338 days
8	Full	Jan. 16, 1976	489 days
9	Partial	Feb. 23-25, 1976	527 days
10	Full	May 3, 4 & 11, 1976	605 days



PRE AND POST SEDIMENT ANALYSIS
SAMPLING STATIONS (COMPOSITE)

FIGURE 3



DREDGE EFFICIENCY SEDIMENT SAMPLING STATIONS

FIGURE 4

(2) Disposal Pond Sediments

The Corps constructed two large dredge spoil disposal ponds based on the estimated amount of PCB contaminated sediments to be removed from Slip 1. [redacted]

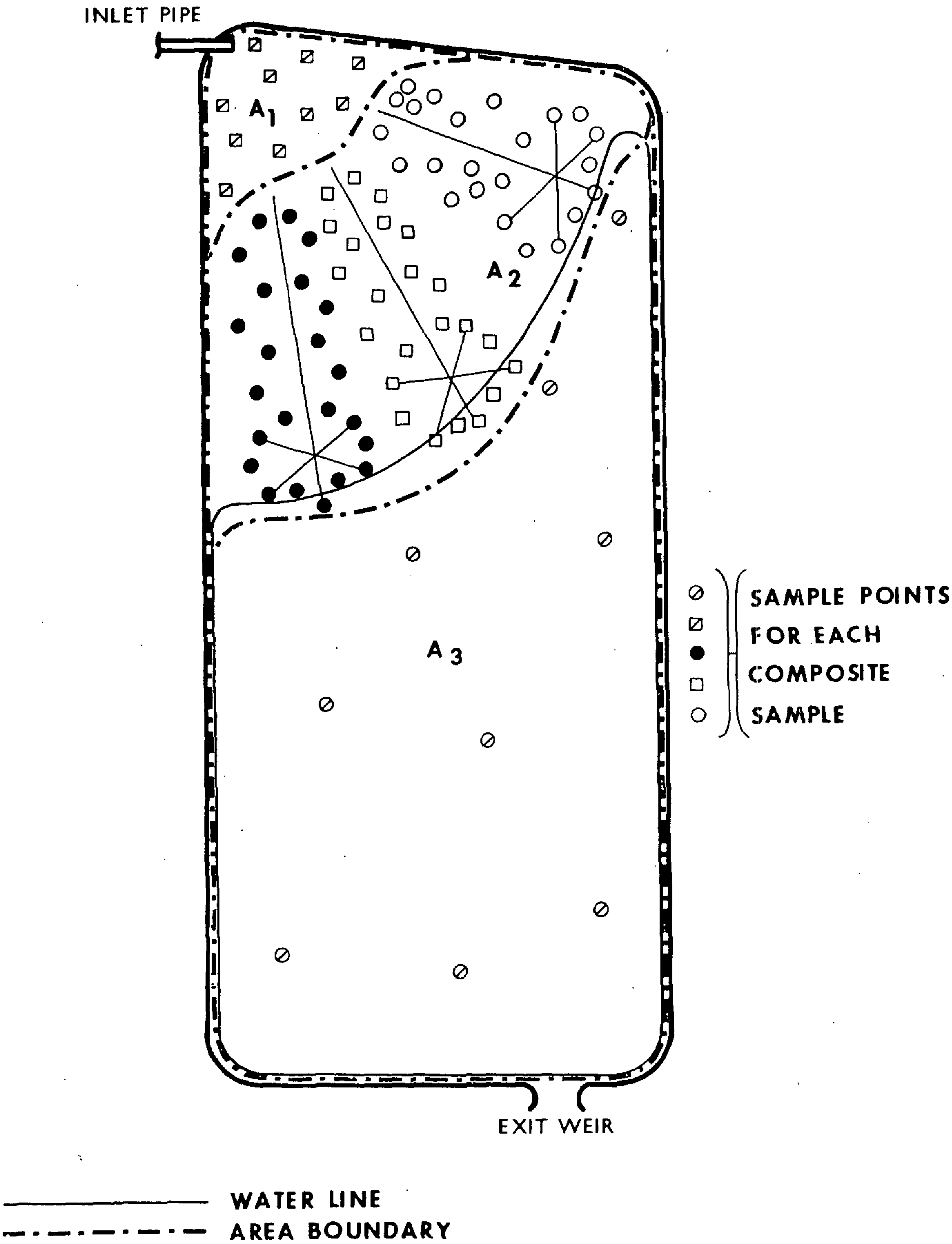
Nine composite samples were obtained from the pond. Although only one surface composite was made for area A1, three surface and three total core composites (one pair per transect shown in Figure 5) were taken for Area A2. Also, one surface and one total core composite were obtained from the area A3.

(3) Influents to Disposal Ponds

Collection of composite disposal pond influents was accomplished in the following manner. A sample taken from the influent stream using a pretreated three liter bucket was distributed into containers specially treated for holding metal, nutrient, oil and grease and chlorinated hydrocarbons samples starting with that designated for metals. A second sample was taken and distributed beginning at the nutrient container. The process was repeated, each time advancing the start to the next container, until the vessels were filled to the desired volume. A sampling period of fifteen to twenty five minutes was used to insure a representative sample of the dredging activities for the time of sampling. The composites were sealed and returned to the laboratory for immediate analysis.

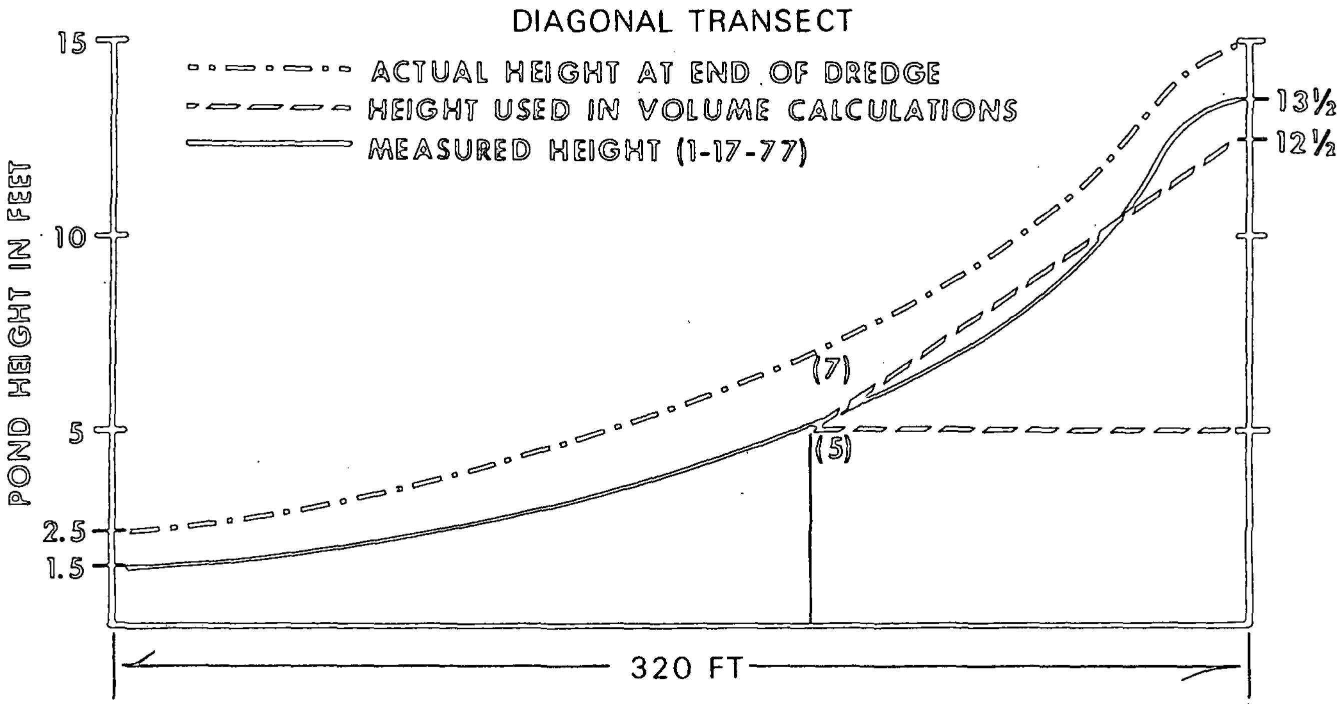
Influent sampling dates along with areas in which the dredge was working at time of sampling are shown in Table 2 (See Figure 3). Originally, the influent sampling scheme included taking pairs of samples at the start, in the middle and toward the end of the dredge activities. Unfortunately, several dredge equipment failures made it impossible to predict when influent sampling could be carried out. The "Dredging Production Report" shown in Table 3 illustrates the problem. Therefore, samplings were spaced randomly.

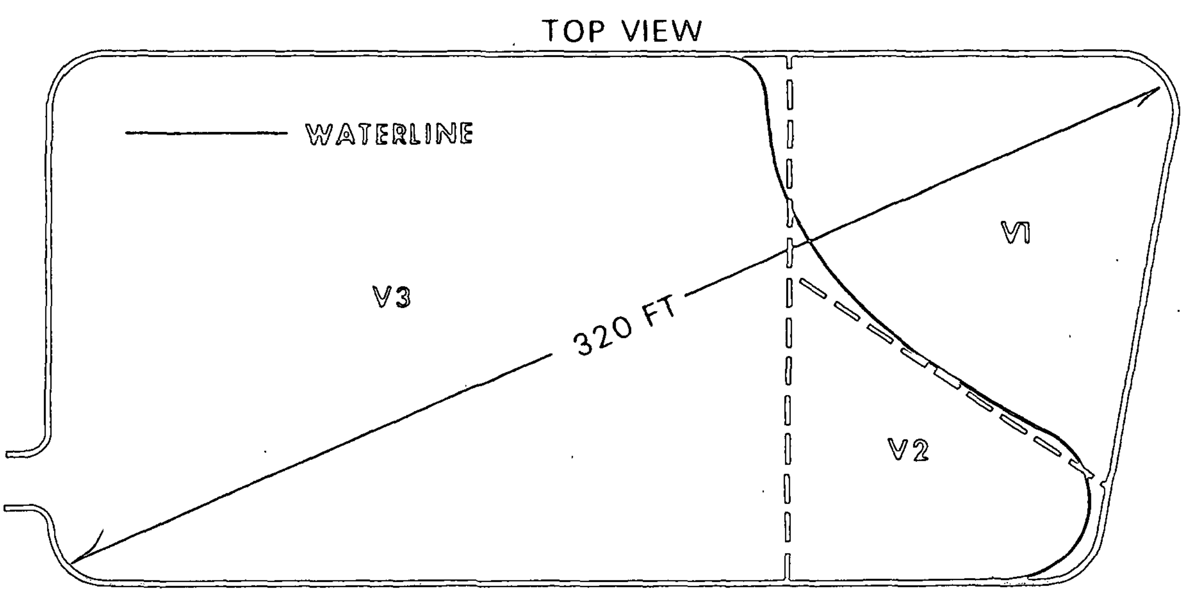
FIGURE 5



COMPOSITE DREDGE SPOILS SAMPLING SITES FOR POND 1

FIGURE 6





DREDGE SPOIL TOPOGRAPHY POND 1

Table 2. DREDGE SPOIL POND INFLUENT SAMPLING FREQUENCY

Date	Dredge Working in Area
March 16, 1976	5 and 6
March 19, 1976	3 and 4
March 22, 1976	3
March 22, 1976	1 and 2
March 23, 1976	1 (near spill site)

TABLE 3. DREDGING PRODUCTION REPORT PNEUMA NORTH AMERICA

Date	Working Hours	Dredging Hours	Delays	% Dredging
March 4, 1976	9-50/60	---	---	Test Water
March 5, 1976	8-15/60	4-5/60	4-10/60	49%
March 6, 1976	10	3-5/60	6-55/60	31%
March 8, 1976	10	4-15/60	5-45/60	42%
March 9, 1976	10-40/60	3-24/60	7-16/60	31%
March 10, 1976	10-30/60	0	10-30/60	0%
March 11, 1976	10	3-12/60	6-48/60	32%
March 12, 1976	10	5-53/60	4-7/60	59%
March 13, 1976	10	3-12/60	6-48/60	32%
March 15, 1976	10-30/60	2-4/60	8-26/60	19%
March 16, 1976	10	4-23/60	5-37/60	43%
March 17, 1976	10	0	10	0%
March 18, 1976	10	37/60	9-23/60	6%
March 19, 1976	10-30/60	6-23/60	4-17/60	62%
March 20, 1976	5	0	5	0%
March 21, 1976	5	3-6/60	1-54/60	62%
March 22, 1976	10	5-15/60	4-45/60	52%
March 23, 1976	10	6-42/60	3-18/60	67%
March 24, 1976	10	3-16/60	6-44/60	32%
March 25, 1976	9	0	9	0%
March 26, 1976	9	7-2/60	1-58/60	78%
March 27, 1976	10	5-11/60	4-49/60	51%
March 29, 1976	10	6-11/60	3-49/60	61%
March 30, 1976	5 (up to demobil-ization)	3-56/60	1-4/60	78%

Total working hours 223¼
Total dredging hours 81-1/5 = 36% actual dredging
Total delays 142-1/20

(4) Effluents from Dredge Disposal Ponds

Collection of disposal pond effluents and filtered waters returning to the Duwamish River were made with respect to time and volume. Chlorinated hydrocarbon and oil and grease samples were composited in pretreated two gallon glass jars. Samples used for all other parameters were collected using an ISCO model 1392 auto sampler. Effluent samples were taken only when filter truck pumps were returning disposal pond water to the river. Due to the lack of continuous dredging activity, water from the first of two disposal ponds did not come over the weir until March 12, 1976, eight days after dredging was initiated. Both influent and effluent flow were discontinuous and erratic.

An overview of the disposal site is shown in Figure 7. This includes placement of the filter truck, a small holding pond located between pond 2 and the large EPA carbon filter truck along with influent and effluent sampling points.

(5) River Water

Standard hydrographic samples were collected and analyzed for salinity and dissolved oxygen. Temperature was noted. Nutrient, sulfide, metal and chlorinated hydrocarbon samples were collected by University of Washington personnel under EPA contracts WY-6-00-0451-J and 68-01-3369. Sample collection and handling procedures are outlined in the final report of the contract (3).(See Figure 8 and Tables 4 and 5).

(6) Hydrography

Hydrographic parameters (conductivity and dissolved oxygen) along with pH of pond 2 effluents were monitored continuously using a Model 6 Hydrolab Surveyor equipped with a continuous recorder.

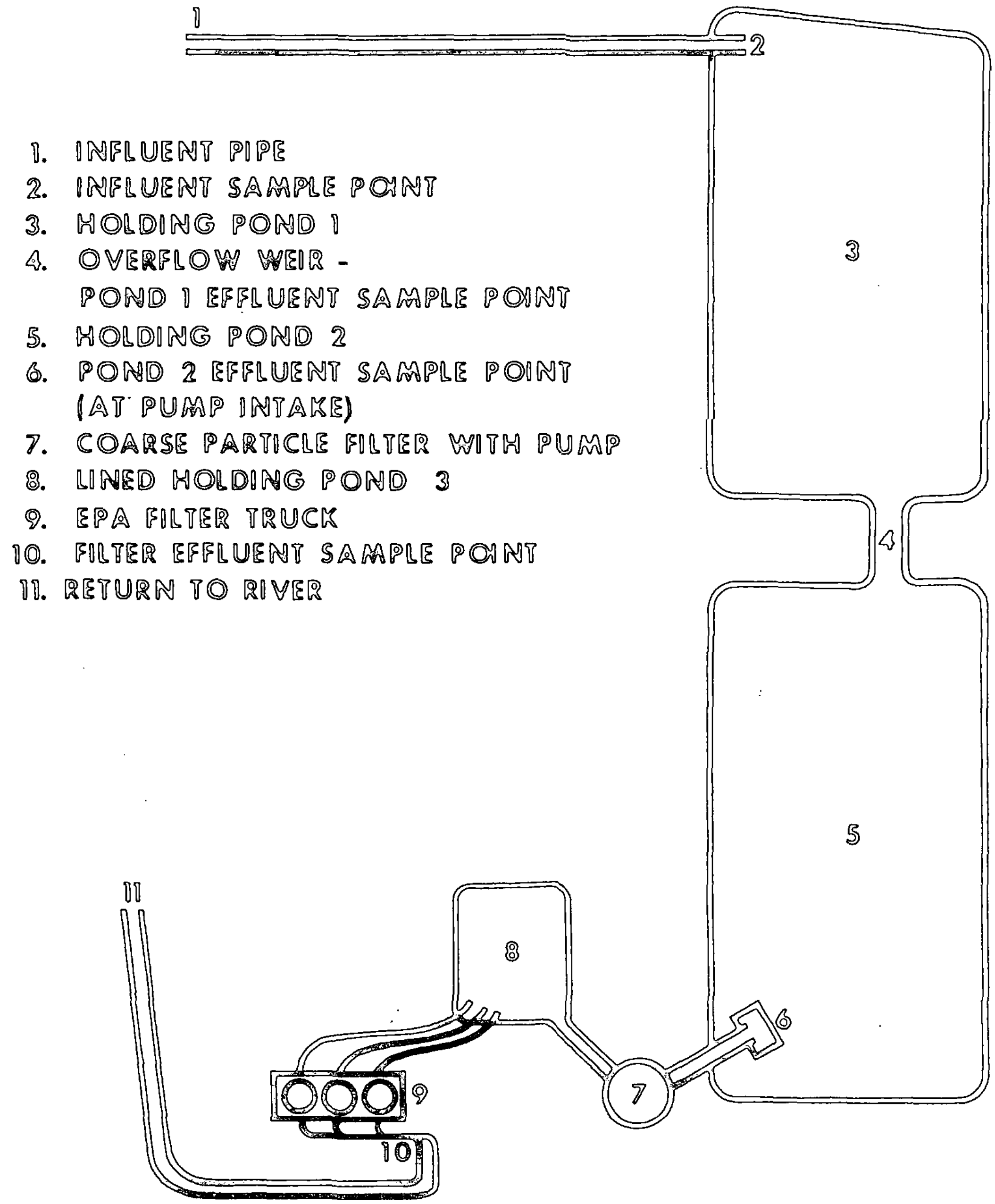
(7) Microbiological

Dredge sediment samples from Slip 1 were withdrawn from each of the six stations with the aid of a Van Veen Sampler. Once on the deck of the boat, a small portion (100-200 g) was transferred to a sterile 8 oz. plastic container using sterile metal spoons. All samples were immediately placed in an ice chest and transported to the laboratory for processing within 2-3 hours.

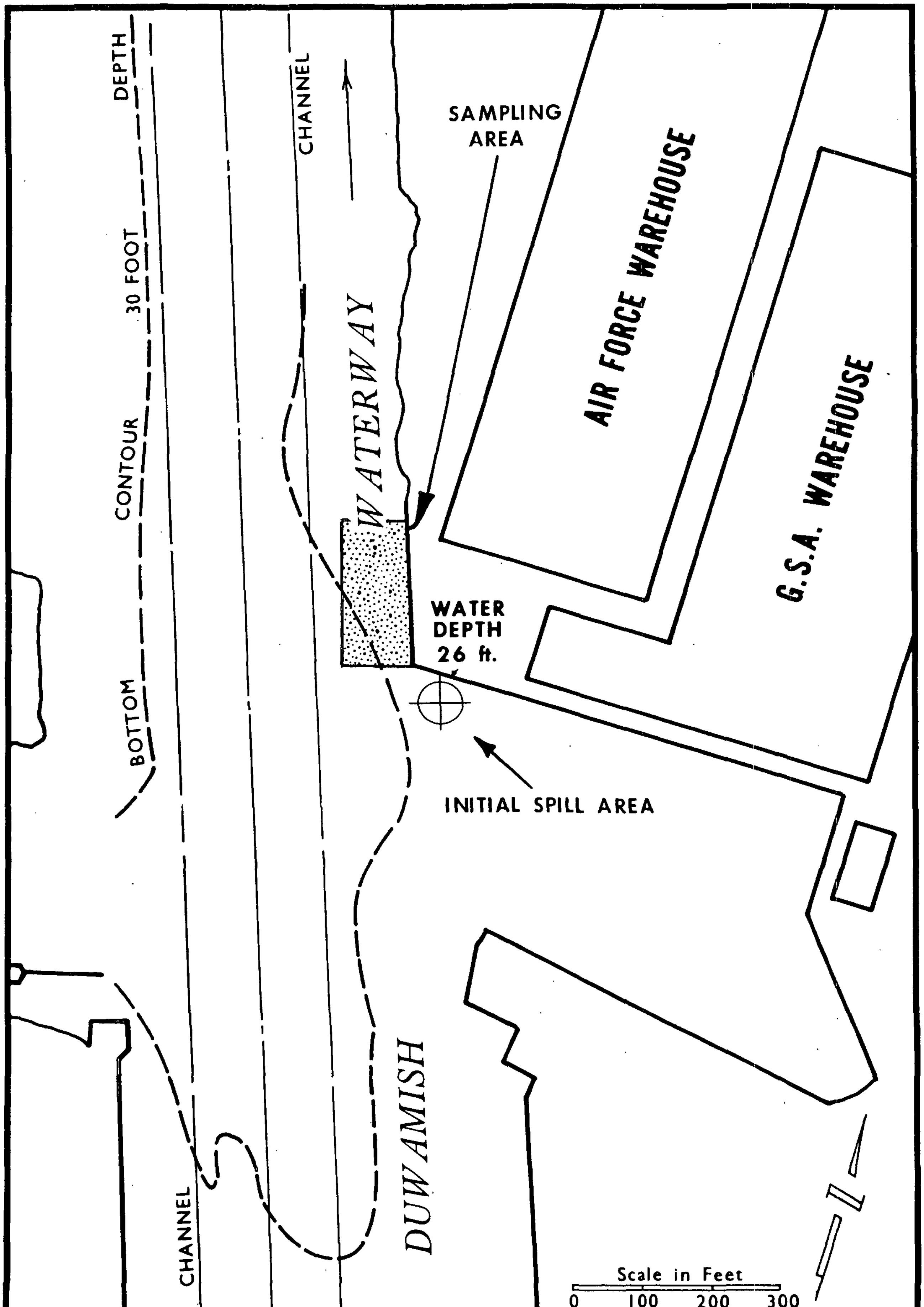
Samples of dredge spoils (water and/or sediment mixed) were collected during dredging from two locations: (1) the influent pipe to disposal pond number one (outlet pipe from dredge) and (2) the effluent pipe from disposal pond number two.

Samples of post-dredge sediments from disposal pond number one were obtained from composites of whole core and surface grab materials. In each case, a 100-200 g. portion of the composite

FIGURE 7



OVERVIEW OF DISPOSAL PONDS
AND TREATMENT FACILITIES



AMBIENT WATER COLUMN SAMPLING AREA (SLIP 1)

FIGURE 8

TABLE 4. CRUISE SCHEDULE FOR MONITORING RIVER WATER AT DREDGE SITE

Cruise No.	Date	Time of Ebb Tide	Sampling Time Interval
1	February 25, 1976	0405 - 0941	0507 - 1003
2	March 6, 1976	0736 - 1427	0815 - 1453
3	March 8, 1976	0849 - 1610	0901 - 1517
4	March 18, 1976	0551 - 1229	0835 - 1343
5	March 22, 1976	0859 - 1610	0934 - 1631
6	March 23, 1976	1009 - 1719	1014 - 1733
7	April 20, 1976	0832 - 1533	0904 - 1440

Table 5. COMPOSITE SAMPLING SCHEME FOR MONITORING RIVER WATER AT DREDGE SITE

Hr. Interval of Ebb at Which Sub Sample was Taken	Dredge Site Station*		Reference Station ‡
	0-1 1-2 2-3	3-4 4-5 5-6	6-7
Surface (Number of Composites per Cruise)	1	1	1
Deep (Number of Composites per Cruise)	2	2	1

* Dredge site samples were taken every hour to generate two 3-hour composites.

‡ Located at 2.99 miles from mouth of Duwamish River.

was placed in a sterile 8 oz. container and immediately transported to the laboratory for analysis.

(B) SAMPLE PREPARATION

Samples were received from the field and held at 4^{o} C. Sample preparation included separation and stabilization steps when necessary. An outline of containers and preservatives used by sample type is found in Table 6.

(1) River Bottom Sediments

Samples of river bottom sediments collected for the purpose of detecting the translocation of PCB's from the Slip 1 spill site into the Duwamish River were homogenized before analysis was conducted. No further preparation was made.

(2) Slip 1 Sediments and Interstitial Water

Composite samples of five areas within Slip 1 were homogenized separately before analysis. A portion of each well mixed sediment was set aside for bulk analysis and another portion was centrifuged using a Sorvall RC2-B high speed refrigerated centrifuge equipped with a GSA rotor operating at 12,500 RPM and 4^{o} C for twenty minutes. Stainless steel or polycarbonate centrifuge tubes were employed for preparation of interstitial water samples for organic chemical analyses and all other parameters, respectively. Interstitial water destined for organic analyses was decanted into glass jars, stored at 4^{o} C and analyzed within 24 hours. The remaining solid was also stored at 4^{o} C in a pretreated glass jar until analysis was performed. Interstitial water destined for other analyses (e.g. metals, nutrients, etc.) was filtered through a 0.45 micron filter, preserved and stored at 4^{o} C in plastic containers. A portion of the interstitial water was left unpreserved and immediate analysis of some parameters (e.g. NO2-) was performed.

(3) Standard Elutriate Test

Portions of the same composite samples used for interstitial water and bulk sediment analyses were used for the standard elutriate test. The test was performed according to the procedures outlined by the U. S. Army Corps of Engineers (4, 5, 6 and 7), except centrifugates used for determination of organic parameters were not filtered. The centrifugates or filtrates obtained from this procedure were stabilized and/or held at 4^{o} C until analysis was performed.

Table 6. SUMMARY OF SAMPLE STORAGE AND PRESERVATION

Analysis	Container	Sampling Device	Amount (Total)	Preservative	Storage Condition
(A) Water Samples					
Oil & Grease	Glass	SS* or Glass	2 gal.	1 ml. H_2SO_4 per liter	4^{o} C
PCB	Glass	SS or Glass	2 gal.	None	4^{o} C
N-TKN $N-NH_3$ P-Total $N-NO_3$	Plastic	Plastic	1 qt.	1 ml. conc. H_2SO_4 per liter	4^{o} C
o-p $N-NO_2$ Sulfide Turbidity	Plastic	Plastic	1 qt.	None	4^{o} C
Metals	Plastic	Plastic	1 gal.	25 ml. re-distilled NHO_3 per liter	RT
(B) Sediment Samples					
All parameters	Glass	SS	8 oz. to 3 gallons	None	4^{o} C
(C) Hydrolab on Ship to Measure Conductivity, D.O., Temperature, and pH					

* SS - Stainless steel

(4) Disposal Pond Sediments

Composite pond sediments were mixed thoroughly, subsampled and stored at 4^{o} C. Analysis of the composites was performed within two weeks of sample collection.

(5) Disposal Pond Influent and Effluent

All samples were resuspended prior to analysis. A portion of the mixture was analyzed immediately for some parameters (e.g. settleable solids, etc.). Other portions were centrifuged, decanted, filtered through a 0.45 micron filter and preserved as described above (See "Slip 1 Sediments and Interstitial Water"). Centrifugate destined for analysis of organic parameters was not filtered. Centrifuged influent solids were stored at 4^{o} C in pre-treated containers. Since little solid was obtained from routine centrifugation of effluents, a continuous high speed Sharples centrifuge was used to collect effluent solids. Approximately 500 liters of effluent was processed at the disposal site over a six day period. Rate of feed of pond effluent to the centrifuge was adjusted so that turbidity of the centrifugate did not exceed 4 JTU. The solids were stored at 4^{o} C until analyses were performed.

(6) River Water

Samples of whole river water and SPM destined for PCB analysis were stored at 4^{o} C until analysis was performed (3). Portions of whole water samples used for all other determinations were preserved when necessary and stored at 4^{o} C. Determination of some parameters subject to rapid degradation was conducted upon receipt of samples.

(7) Microbiological

All sediment and dredge spoil materials were processed in the same manner following recommended procedures (8, 9). Samples were weighed to nearest gram and aseptically transferred to sterile blender jars to which an equal amount, by weight, of 0.1% sterile peptone dilution water was added. The mixture was then blended at ca. 14,000 rpm for 60-120 seconds. Within 2 minutes of the blending period appropriate volumes (or dilutants) were transferred with pipets to the appropriate culture media.

(C) LABORATORY ANALYSIS

(1) Chemical

A variety of chemical and physical parameters were measured in water and sediment samples. Analyses were performed according to methods found in Table 7.

Table 7. ANALYTICAL METHODS FOR MONITORING ACTIVITIES

Parameter	Sample Type	References
(A) Metals (Total)		
As, Cd, Cr, Cu, Fe, Pb, Mn, Ni, Zn	FW, SW	10, 11
	Sd	11, 12
Hg	FW, SW, Sd	10, 11
(B) Nutrients		
N-NH_3, NO_2 , NO_3 , Total P, Dissolved Ortho P	FW, SW	10
(C) Organochlorine Compounds		
PCB	FW, SW, Sd, Fh	13, 14
(D) Miscellaneous		
TOC, COD, Turbidity, N-Kjeldahl, Total Volatile Solids, Total Solids	FW, SW, Sd	10
Settleable Solids	FW, SW	15A
Total Sulfide	FW, SW	15A
	Sd	15B
Salinity	SW	

FW Freshwater
SW Seawater
Sd Sediment
Fh Fish

(2) Microbiological

Total coliform (TC), fecal coliform (FC) and fecal streptococcus (FS) determinations were performed according to Standard Methods (9) using the 5 tube, multi-dilution MPN procedure. Bacteriological analysis also included the anaerobic enumeration of *Clostridium perfringens* (welchii) on sulfite-polymyxin-sulfadiazine (SPS) agar. All confirmatory steps employed for *C. perfringens* followed those outlined in the *Bacteriological Analytical Manual* (16) published by the Food and Drug Administration. In addition to an anaerobic determination, a 5 day, 20° C aerobic plate count was performed on all samples using tryptone glucose yeast (TGY) agar.

Part IV. RESULTS AND DISCUSSION

An extensive monitoring effort was initiated only days after PCB's were accidentally spilled into the Duwamish River at Slip 1. Significant amounts of PCB's remained in the sediment after the original clean-up and a dredging operation was planned and conducted by the Corps of Engineers. Since appreciable time elapsed between the initial clean-up and final removal, extensive monitoring was required to identify movement of the toxic material. The results of the entire monitoring program is described best in terms of three phases: pre-dredge activities, monitoring during dredging, and post-dredge evaluation.

(A) PHASE I. PRE-DREDGE ACTIVITIES

(1) Identification of Pollutant

Questions regarding the type of Aroclor spill at Slip 1 were raised when laboratory results conflicted with transformer label information. As a consequence, gas chromatography/mass spectrometry (GC/MS) analysis was performed on extracts of bottom sediments saturated with the spilled fluid, recovered sludge and a standard of Aroclor 1242. Results of GC/MS analysis are presented in Appendix B. Figures B-1, B-2, B-3 and B-4 show constructed gas chromatograms (RGC) of the three samples. Limited mass chromatograms (Figures B-5, B-6, B-7 and B-8) with M+/e=256-261 show patterns indicative of Aroclor 1242 PCB isomers containing 3 chlorine atoms. Similarly, limited mass chromatograms (Figures B-9, B-10, B-11 and B-12) using M+/e=290-300 give patterns expected for Aroclor 1242 PCB isomers with 4 chlorine atoms. Corresponding mass spectra for each sample type are shown in Figures B-13, B-14 and B-15. The spectra are identical. Analysis of the spectra show molecular ion clusters typical of chlorinated biphenyls with 3 chlorine atoms along with strong P-70 cluster beginning at M+/e=186. This is indicative of the loss of Cl_2. Comparison of above RGC's and spectra of sediment and sludge sample extracts with those of Aroclor 1242 PCB standard shows Aroclor 1242 PCB to be present in both.

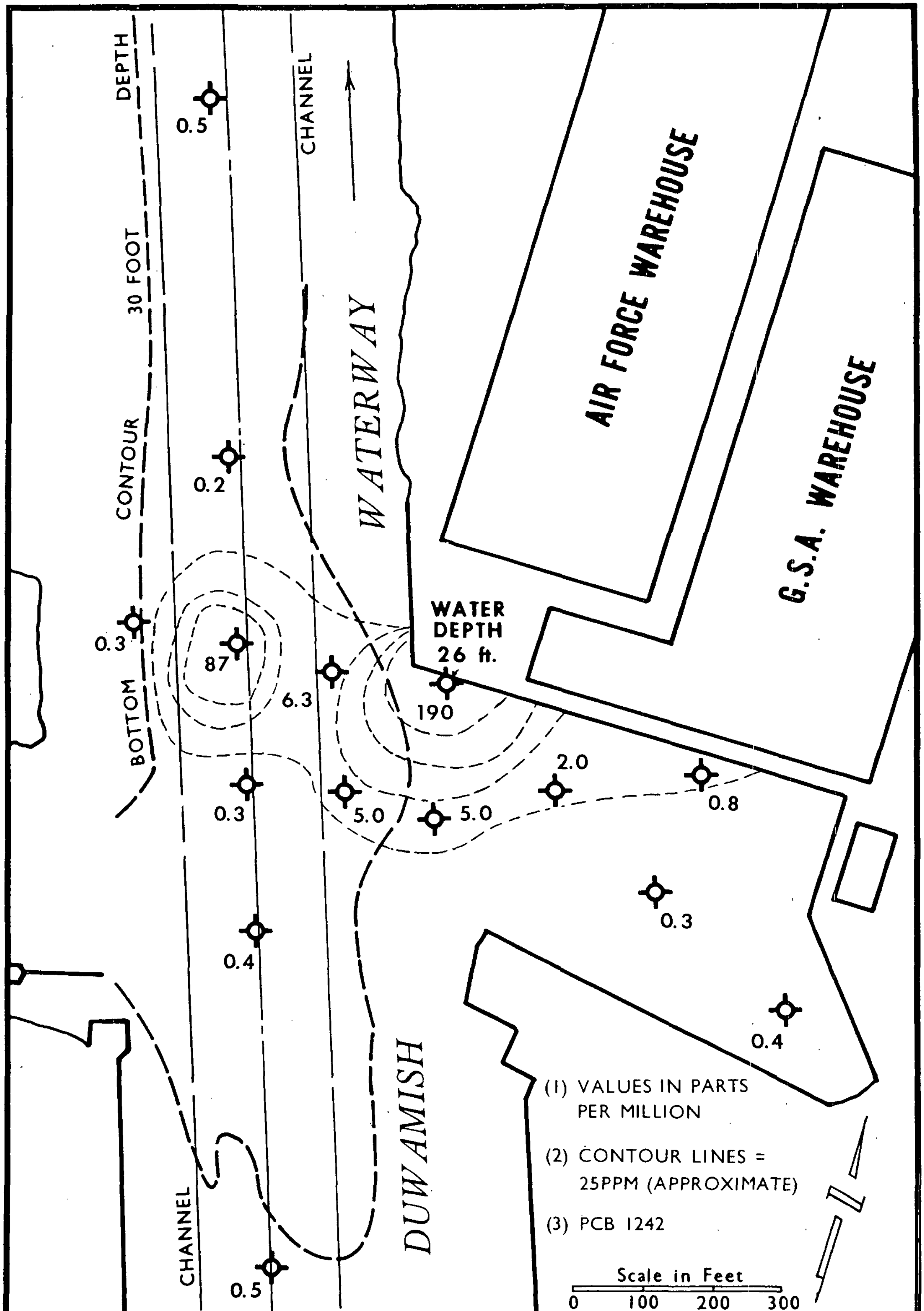
Analysis by gas chromatography/electron capture (GC/EC) gave similar results. Chromatograms of the transformer fluid, extracts of bottom sediments, recovered sludge and of standard Aroclor 1242 were identical. The spilled fluid was identified as Aroclor 1242 by both GC/MS and GC/EC.

(2) Translocation of PCB's

An initial survey of PCB burden in sediments in and around Slip 1 was conducted within five days after the spill occurred on September 13, 1974. Analysis of survey results indicated two areas of high PCB concentration, one at the impact site and another approximately 300 feet to the west (Table 8, Figure 9). Subsequent surveys of September 25, 1974 and October 18, 1974, conducted during initial clean up efforts, indicated some movement of PCB's in the slip and river channel (See Tables 9 and 10, Figures 10 and 11). This was in agreement with observations of divers, who noted movement of PCB pools on the river bottom.

A discrepancy between initially reported low PCB levels at the spill site and higher values of later surveys was noted. This anomaly can be accounted for by considering the manner in which the samples were taken. The initial survey was conducted without knowledge of the exact point of transformer impact. As a consequence, a fringe area fifty feet west of the spill site was sampled but later surveys produced samples from the center of the impact site. The result was similar sediment samples with divergent PCB concentrations. Another survey designed to detect translocation of PCB into the river was conducted after initial clean up operations were completed (See Table II and Figures 12 and 13). Movement of PCB contaminated sediment was found to have occurred. Analysis of results indicate some of the material made its way into the river channel during the first clean up operation.

Three surveys of PCB burden in the river bottom sediment were made during the time period after the first clean up attempt to the start of the second. On February 20, 1975, a limited survey of the spill site, consisting of stations 225 and 231, was performed to determine if PCB had in fact migrated out of the slip. Comparison of this data with that obtained from previous surveys shows little change in sediment PCB burden since termination of initial clean up operations on October 31, 1974 (See Table 12). Translocation of PCB's on the river bottom, first noted on November 4, 1974, was studied again in 1975. Analysis of surface sediment (See Tables 13 and 14, Figures 14, 15, and 16) indicates some Aroclor 1242 movement into the river and upstream to a point just south of Slip 1 between 81 + 00 feet and 91 + 00 feet. Also, it is evident that Aroclor 1242 had migrated towards the back of the Slip and that observed surface values of PCB in the sediments were much lower than previously reported. Since only the top few centimeters of sediment were analyzed, it was possible to detect not only the translocation of PCB but also dilution of PCB "hot spots" by sedimentation from spring run off. Analysis of the bottom one third portion of core samples at the spill site show elevated PCB levels. It appears that two phenomena were occurring. First, normal sedimentation, 15 cm/yr. at the First Avenue Bridge (17), was covering up contaminated sediments. Second, some force was present to account for mixing and spreading the contaminated sediments throughout the slip. It is known from observation that the Bureau of Indian Affairs (BIA) ship Northstar



P C B SEDIMENT CONCENTRATION (PRE-CLEANUP)

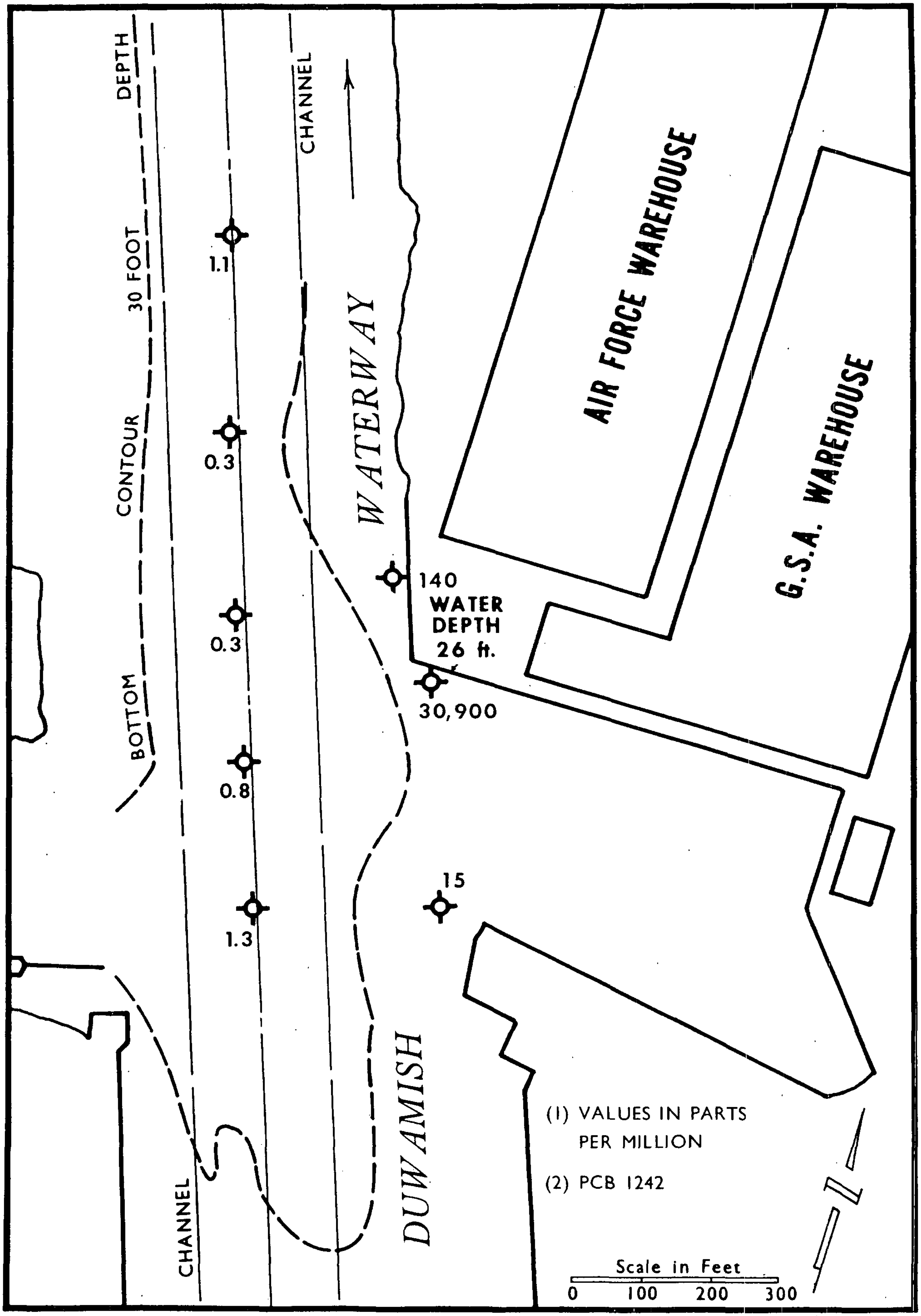
SEPT. 18, 1974

FIGURE 9

Table 8. ANALYSIS FOR PCB'S IN SEDIMENTS TAKEN FROM SLIP 1 (9-20-74)‡

Station Number	1248/54	1242	Station Number	1248/54	1242
201	0.192	0.33	221	0.30	0.20
202	-	-	222	0.18	0.14
203	0.34	0.24	223	-	5.0*
204	0.43	0.23	224	-	5.0*
205	0.39	0.35	225	-	190*
206	0.09	0.06	226	-	2.0*
207	-	0.50*	227	-	0.80*
208	4.25	1.9	228	-	0.30*
209	0.11	0.11	229	-	0.40*
210	0.15	0.06			
211	0.35	0.30			
212	-	-			
213	-	-			
214	0.40	0.20			
215	-	0.50*			
216	0.28	0.11			
217	-	0.20*			
218	-	6.3 *			
219	-	87*			
220	0.27	0.12			

* PCB concentrations based only on Aroclor 1242
‡ Concentrations expressed in microgram/gram, wet weight (ppm)



PCB SEDIMENT CONCENTRATION

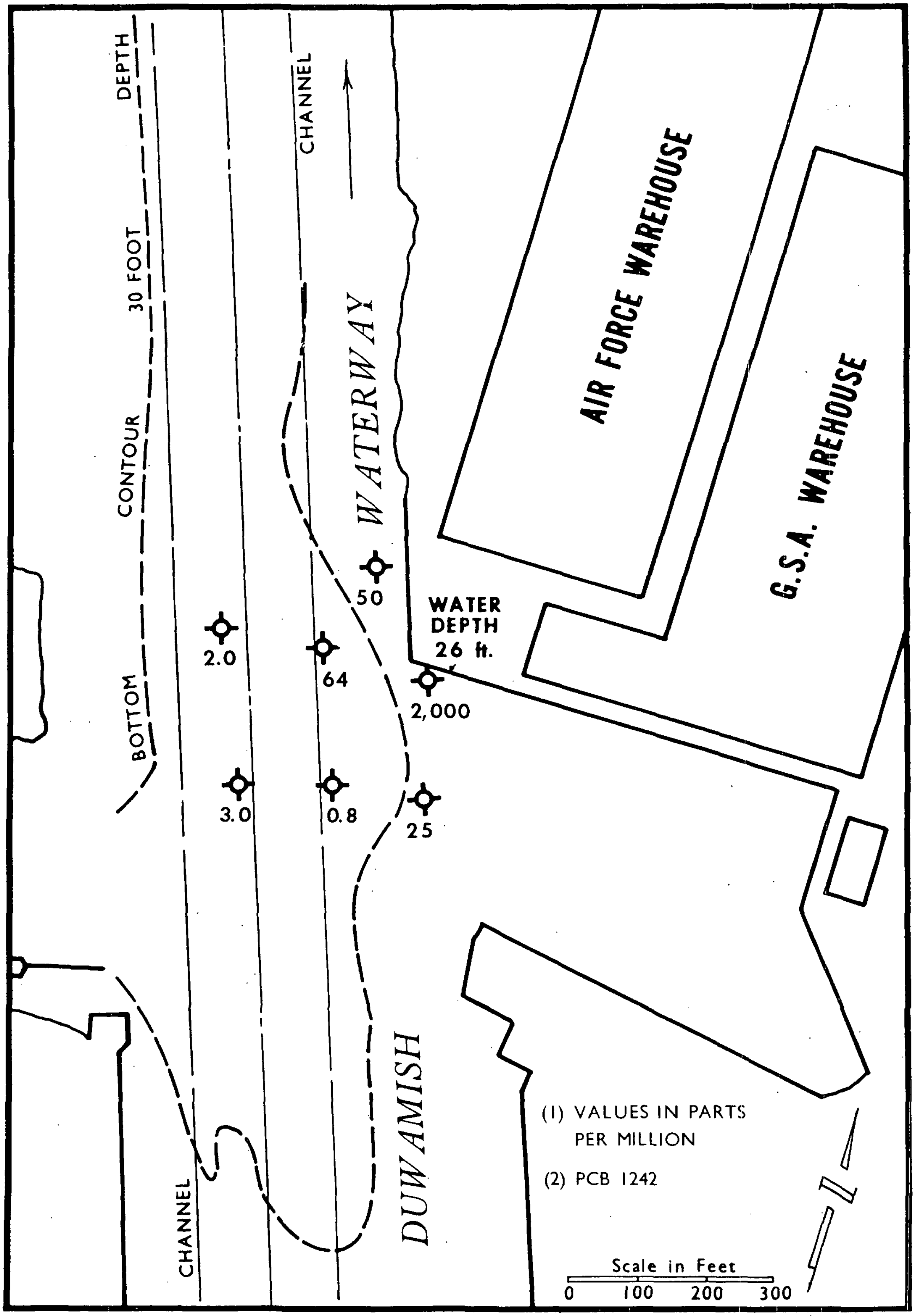
SEPT. 25, 1974

FIGURE 10

Table 9. PCB IN SEDIMENTS TAKEN FROM SLIP 1 (9-25-74)*

Station Number	1248/54	1242
209	0.56	1.3
216	0.61	1.07
217	0.25	0.25
219	0.27	0.23
222	0.69	0.76
225	-	30,900
230	-	15
231	-	140

* Concentrations expressed in microgram/gram, wet weight (ppm)



P C B SEDIMENT CONCENTRATION

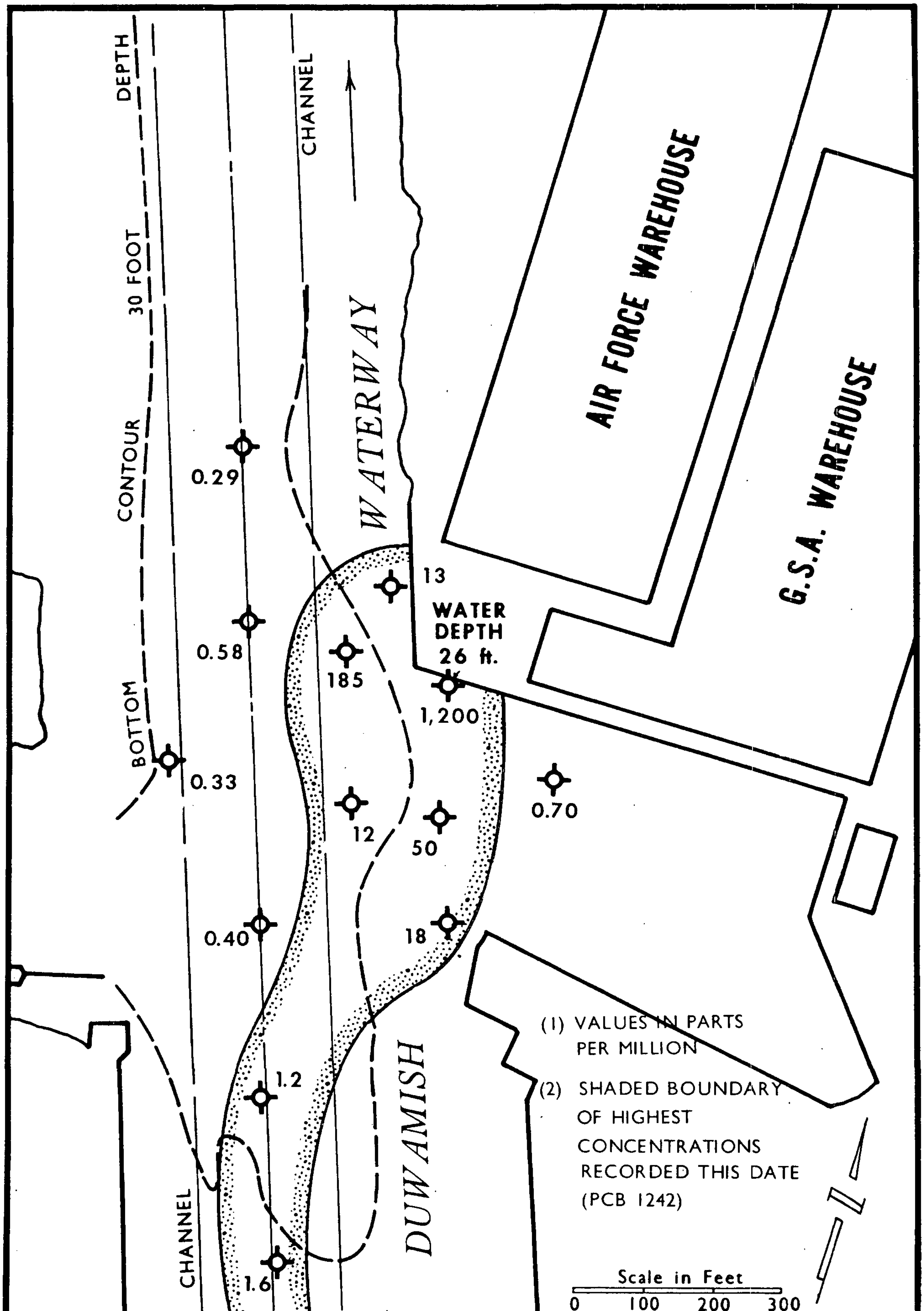
OCT. 18. 1974

FIGURE 11

Table 10. PCB IN SEDIMENT TAKEN FROM SLIP 1 (10-18-74)*

Station Number	1248/54	1242
218	-	64
219	-	2.0
222	-	3.0
223	-	0.8
224	-	25
225	-	2,000
231	-	50

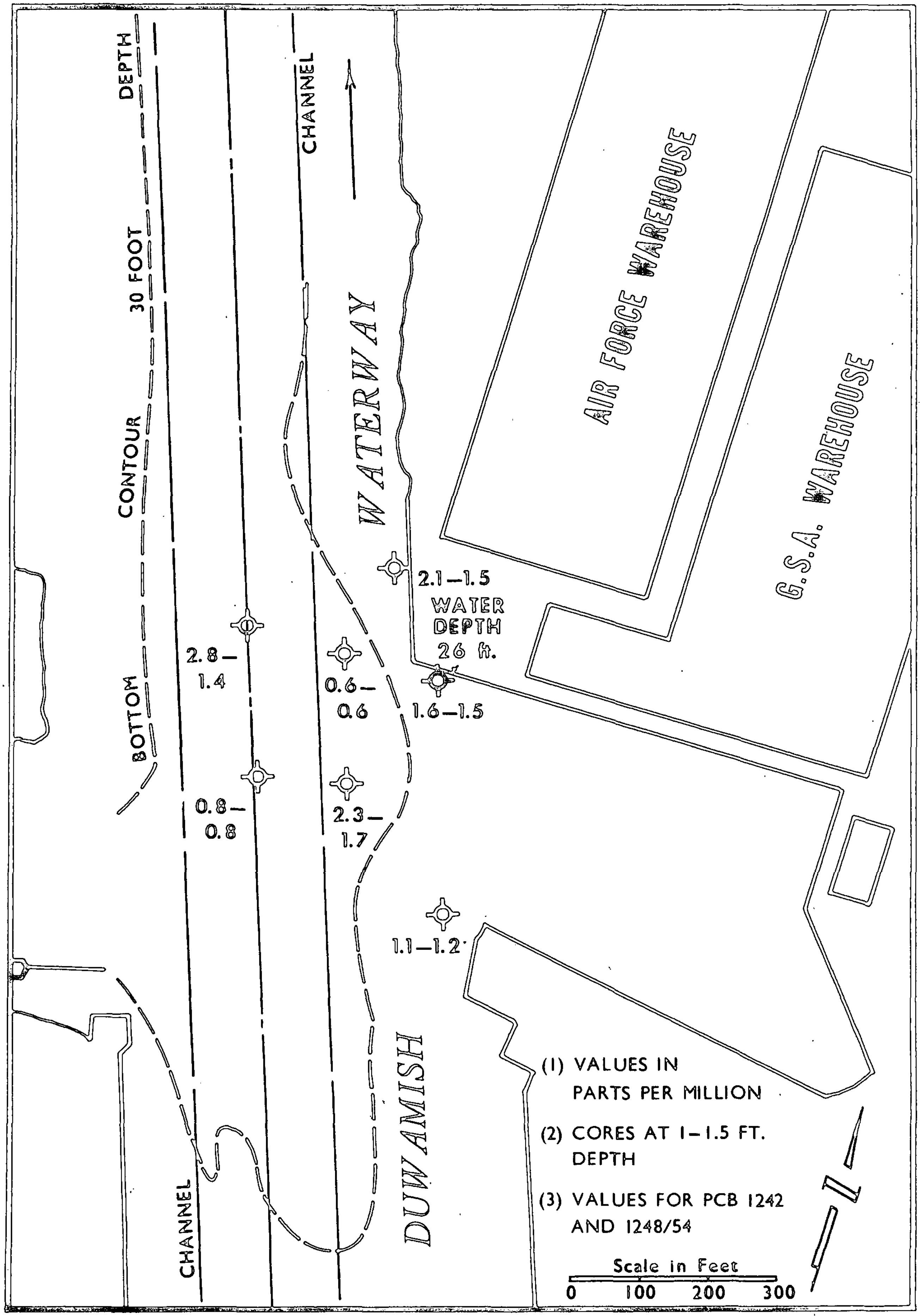
* Concentrations expressed in microgram/gram, wet weight (ppm)



PCB SEDIMENT CONCENTRATION

NOV. 4, 1974

FIGURE 12



P C B SEDIMENT CONCENTRATION IN CORES

NOV. 4. 1974

FIGURE 13

Table 11. PCB IN SEDIMENT TAKEN FROM SLIP 1 (11-4-74)*

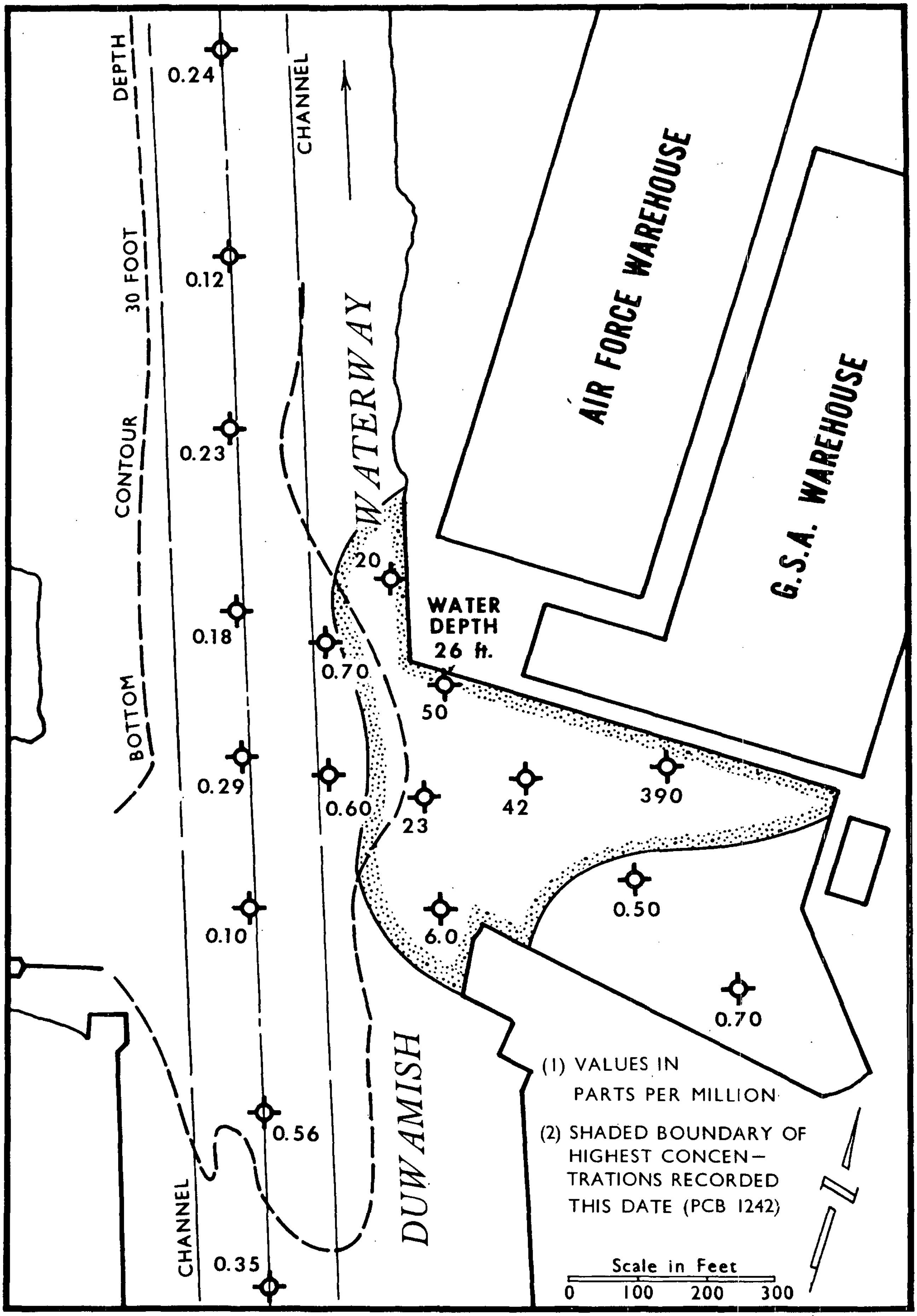
Station Number	1248/54	1242	Station Number	1248/54	1242
201	0.25	0.69	224	-	50
202	0.32	0.41	225	-	1200
203	0.23	1.2	226	0.12	0.70
204	0.28	0.43	227	0.13	0.09
205	0.19	1.5	228	0.20	0.16
206	0.36	1.2	229	0.73	0.25
207	0.35	1.6	230	1.23	18
208	0.36	1.2	231	-	13
209	0.28	0.45	232	0.29	0.97
211	0.49	0.48	233	0.15	0.36
212	0.29	0.57	234	1.11	0.22
213	0.41	0.35	235	-	0.03
214	0.52	0.44	236	0.34	0.28
215	0.37	0.33			
216	0.28	0.38	218 core	0.6	0.6
217	0.40	0.29	219 core	1.4	2.8
218	-	185	222 core	0.8	0.8
219	0.23	0.58	223 core	1.7	2.3
220	0.09	0.09	225 core	1.5	1.6
221	0.34	0.34	230 core	1.2	1.1
222	0.25	0.44	231 core	2.1	1.5
223	-	12			

* Concentrations expressed in microgram/gram, wet weight (ppm)

Table 12. PCB IN SEDIMENTS AT SELECTED STATIONS*

Time	Station 225	Station 231
9-25-74	30,900	140
10-18-74	1,900	50
11-4-74	1,200	13
2-20-75	1,300	60

* Concentrations Aroclor 1242 expressed in micrograms/gram, wet weight (ppm)



PCB SURFACE SEDIMENT CONCENTRATION

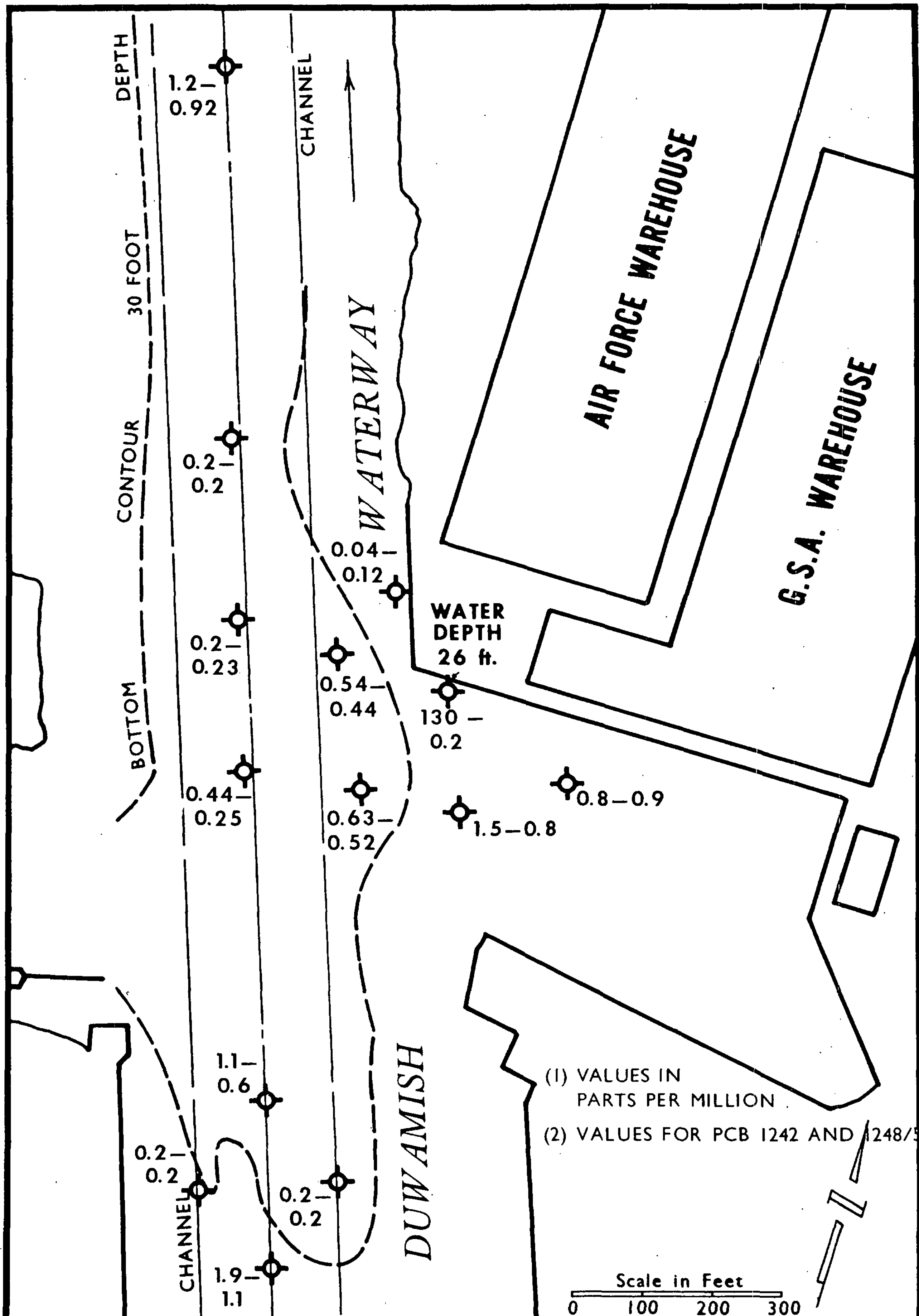
JUN. 2, 1975

FIGURE 14

Table 13. PCB IN SEDIMENTS TAKEN FROM SLIP 1 (6-2-75)*

Station Number	1248/54	1242
202	0.06	0.15
203	0.16	0.37
205	0.05	0.17
207	0.12	0.35
208	0.17	0.56
209	---	0.07
213	0.02	0.18
215	0.11	0.24
216	0.04	0.12
217	0.06	0.22
218	0.01	0.75
219	0.05	0.19
222	0.06	0.28
223	0.14	0.61
224	---	23
225	---	50
226	---	42
227	---	390
228	0.07	0.46
229	0.14	0.64
230	---	6
231	---	21
Recoveries		76-96%
Blanks	<0.10	<0.01

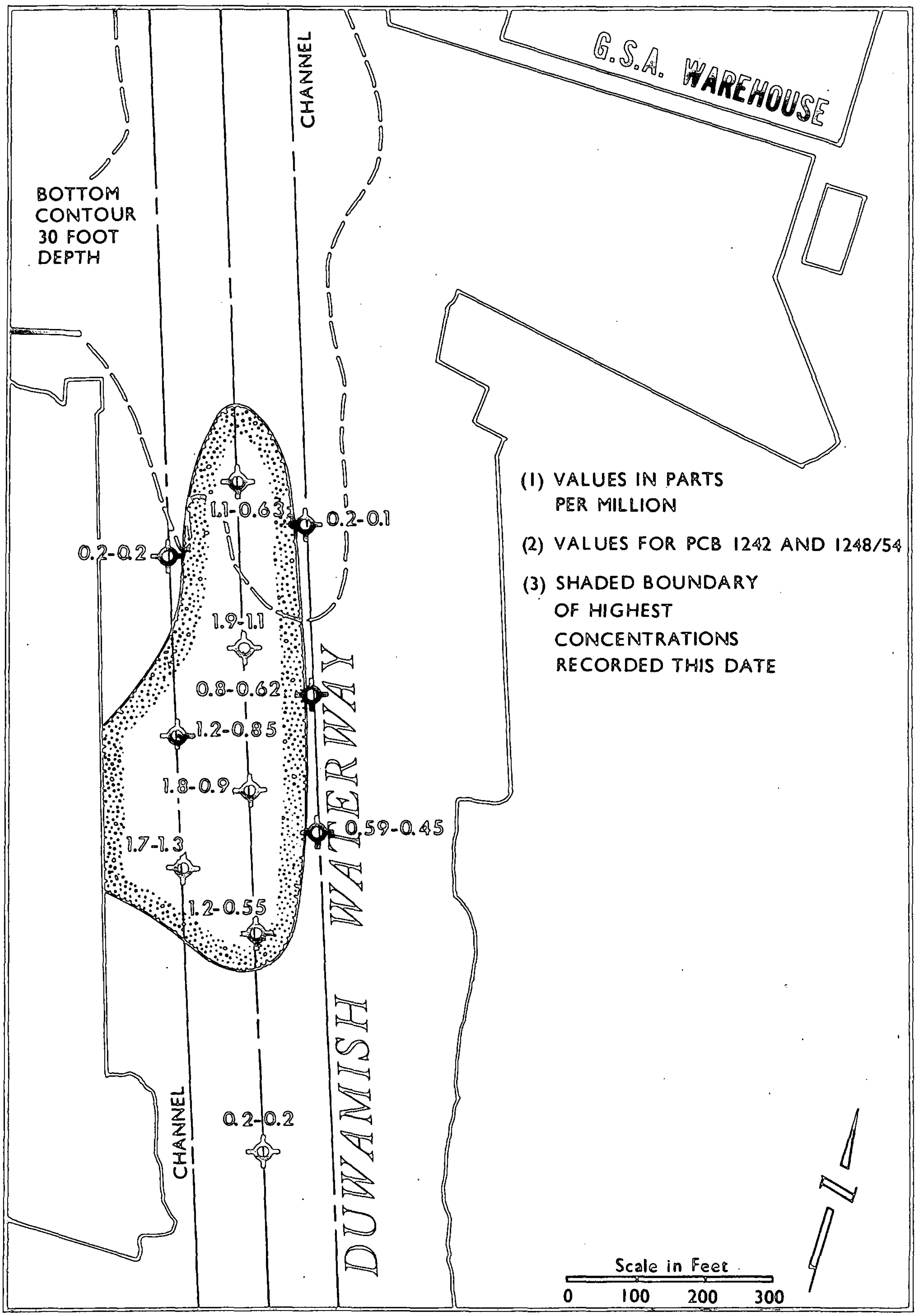
* Concentrations expressed in microgram/gram, wet weight (ppm)



PCB SEDIMENT CONCENTRATION (BOTTOM 1/3 OF CORES)

AUG. 18. 1975

FIGURE 15



P C B SEDIMENT CONCENTRATION (BOTTOM ONE-THIRD CORES)

AUG [illegible] 1975

FIGURE [illegible]

Table 14. PCB IN SEDIMENT CORES (8-18-75)*‡

Station Number	Core Depth in Inches Inside/Outside	Conc. in PPM Wet Wt. 1248/54	1242
202	7/22	<0.2	<0.2
203	9/22	<0.2	<0.2
205	7/22	0.55	1.2
206	8/16	0.9	1.8
206E	8.5/28	0.45	0.59
206W	7/16	1.3	1.7
207	8/18	1.1	1.9
207E	8/24	0.62	0.82
207W	8/20	0.85	1.2
208	9/25	0.63	1.1
208E	7/24	<0.2	<0.2
208W	10/24	<0.2	<0.2
215	7/22	0.92	1.2
217	10/22	<0.2	<0.2
218	6/18	0.44	0.54
219	6/18	0.23	<0.2
222	9/23	0.25	0.44
223	8/19	0.52	0.63
224	7/14	0.8	1.5
225	8/18	---	131
226	9/19.5	0.9	0.8
231	8/18	0.12	0.04
$Blank_1$	---	---	---
$Blank_2$	---	---	---
$Recovery_1$	---	---	103%
$Recovery_2$	---	---	106%
$Recovery_3$	---	---	102%

* Concentrations expressed in microgram/gram, wet weight (ppm)

‡ Values are for bottom one third of core sample only

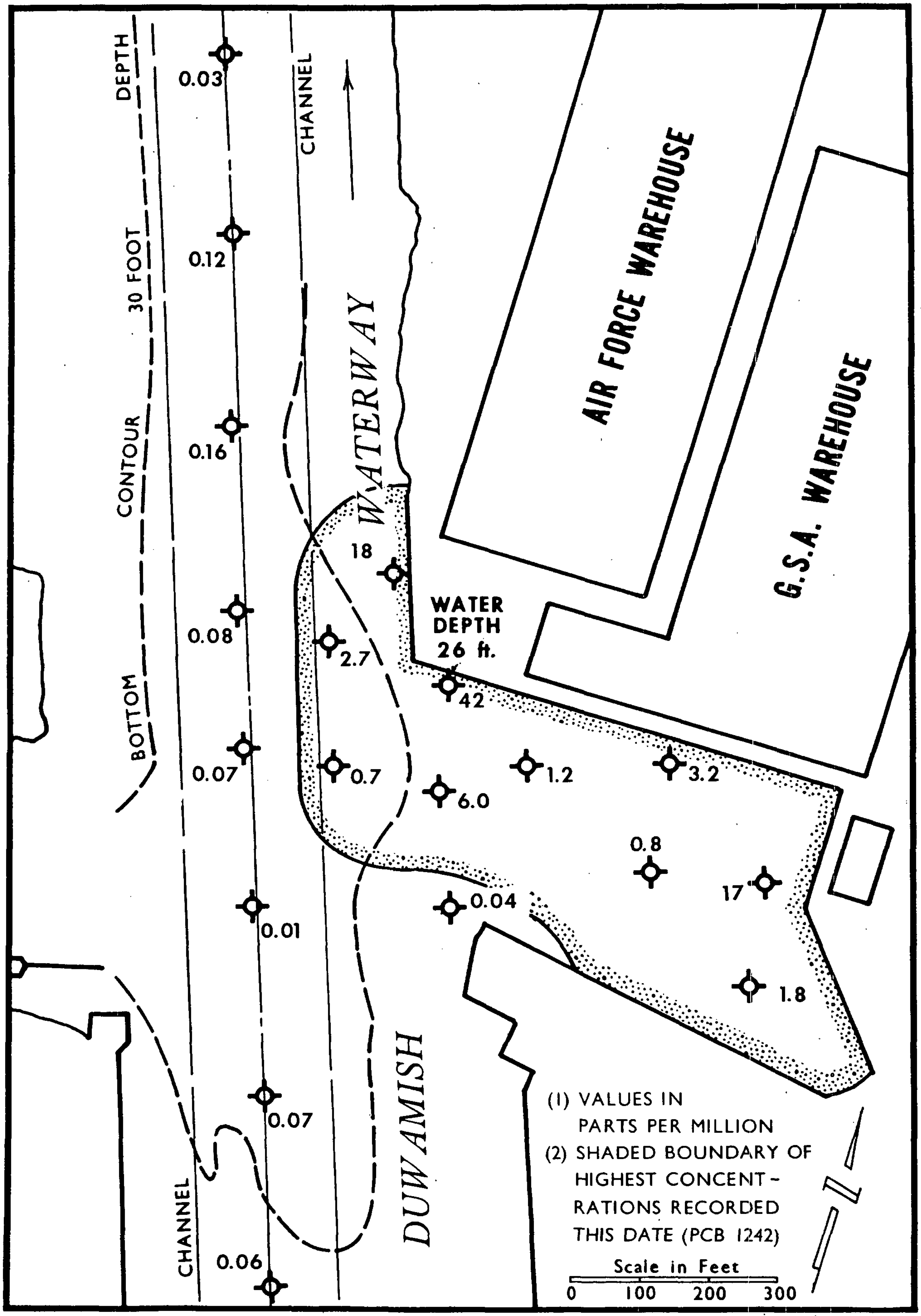
moved into and out of the slip directly over the impact area several times during this period. It is postulated that prop-wash from attempts to maneuver the ship and tidal action were the responsible mixing forces. Yet another survey of sediment PCB burden was carried out on January 16, 1976 before the second clean up effort began. Since the winter of 1975/1976 brought a "20-year flood" with all its effects upon the Duwamish River, it was felt that the spilled PCB's might have been spread by flood action throughout the river channel. Comparison of results of the January 16, 1976 survey (See Table 15, Figures 17 and 18) with previously obtained data indicate that substantial diluting, scouring, and spreading of PCB contaminated surface sediments did occur. The flood action either removed or diluted Aroclor 1242 in river channel sediments between river markers 81 + 00 to 91 + 00 feet.

(3) Characterization of Sediments

Analysis of composite samples representative of Slip 1 sediments one foot deep indicated that several pollutants were present in large quantities (See Table 16, Appendix C and D). For example, the portion of Slip 1 sediments that was dredged contained 2.6 tons of Mn, 3.6 tons of Zn, 6.3 tons of Total-P, 8 tons of oil and grease and 250 tons of Fe along with smaller amounts of Hg, Cd and As. Taken altogether, the amount of pollutants were approximately 300 of an estimated 8,000 tons of material dredged, or 4% by weight.

(4) Predictive Test

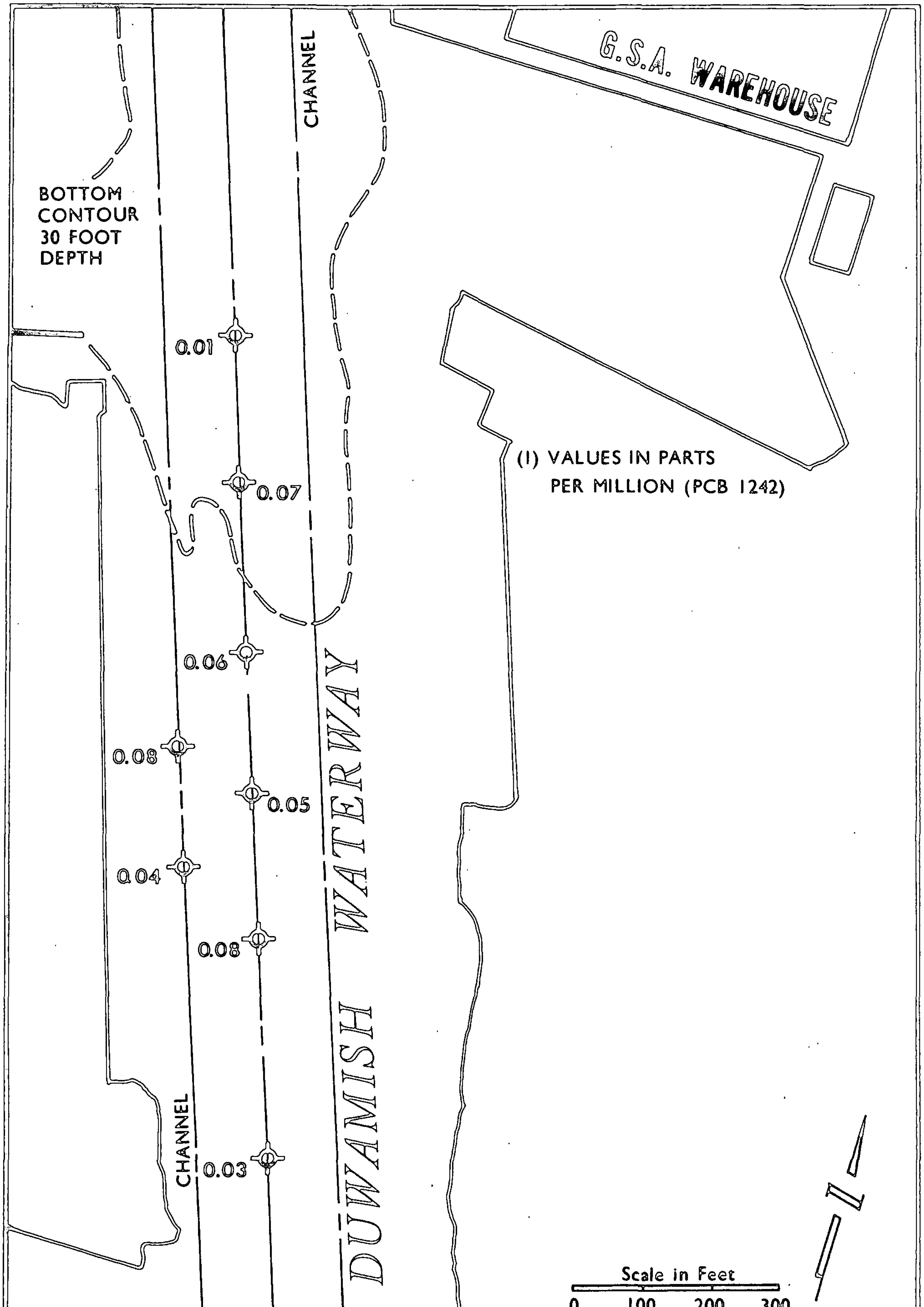
The pre-dredge survey on February 23, 1976 was made to provide information regarding the suitability of Slip 1 sediments for dredge spoil disposal. The Corps of Engineers planned to dispose of the sediments on land. This presented an opportunity to check the validity of the Standard Elutriate and other tests currently used by the Corps to predict the amount of pollution released into return waters resulting from a hydraulic pipeline dredge. Two tests, the "Standard Elutriate Test" and "interstitial water evaluation", were studied. A comparison of test results with observed levels of pollution in return waters is found in Table 16. (See Appendices C and D for supporting data and formula used to arrive at values found in Table 16). In general, observed values of pollutants returning to the river fall between those predicted by either test. The values obtained using "interstitial water evaluation" are lower than observed and those values obtained using the "Standard Elutriate Test" give mixed results (See Table 17). 50% of the pollutants tested are predicted correctly by the "Standard Elutriate Test" within ± two times (2X) the observed amount. Only 8% tested by the "interstitial



PCB SEDIMENT CONCENTRATION

JAN. 16, 1976

FIGURE 17



PCB SEDIMENT CONCENTRATION

JAN. 16, 1976

FIGURE 18

Table 15. PCB IN SLIP 1 SEDIMENTS (1-16-76)*

Station Number	1248/54	1242	Total PCB
203	0.05	0.03	0.08
205	0.08	0.08	0.16
206	0.06	0.05	0.11
206W	0.05	0.04	0.09
207	0.06	0.06	0.12
207W	0.08	0.08	0.16
208	0.09	0.07	0.16
209	0.05	<0.01	0.05
211	0.03	0.04	0.07
213	0.11	0.09	0.20
215	0.08	0.03	0.11
216	0.11	0.12	0.23
217	0.19	0.16	0.35
218	-	2.7	2.7
219	0.15	0.08	0.23
222	0.08	0.07	0.15
223	-	0.70	0.70
224	-	6.0	6.0
225	-	42.	42.
226	-	1.2	1.2
227	-	3.2	3.2
228	-	0.8	0.8
229	-	1.8	1.8
230	0.06	0.04	0.10
231	-	18.	18.
250	-	17.	17.
206 Dup.	0.10	.04	0.14
223 Dup.	0.20	0.30	0.50
Recoveries 80.5-95%			
Blanks	<0.01	<0.01	<0.01

* Concentrations expressed in microgram/gram, wet weight (ppm)

Table 16. PREDICTIVE TEST ANALYSIS SUMMARY

Parameter	Total Possible Release (grams)	Predicted Releases: Elutriate Test grams	(%)	Predicted Releases: Interstitial Water grams	(%)	Actual Total Return to River grams	(%)	Amount of Pollutant Due to River Water in Dredge Return Water (grams)	Amount of Pollutant in Return Water Due to Dredge Operation grams	(%)	Predictive Test That Came Closest To: Actual	Predictive Test That Came Closest To: Adjusted Actual
As	73,000	450	(0.62)	80	(0.11)	250	(0.34)	80	170	(0.23)	ET	IW
Cd	17,000	160	(0.94)	15	(0.09)	90	(0.53)	<80	90	(0.53)	ET	ET
Cr	240,000	1,500	(0.63)	110	(0.05)	750	(0.31)	1,100	0	(0.0)	ET	IW
Cu	440,000	200	(0.05)	20	(0.005)	2,200	(0.50)	1,000	1,200	(0.27)	-	ET
Fe	230,000,000	14,000	(0.01)	35,000	(0.02)	180,000	(0.08)	15,000	165,000	(0.07)	IW	IW
Mn	2,400,000	72,000	(3.0)	12,000	(0.5)	33,000	(1.4)	2,000	31,000	(1.3)	ET IW	ET IW
Hg	1,000	6	(0.6)	1	(0.1)	6	(0.6)	8	0	(0.0)	ET	IW
Ni	150,000	<100	(<0.07)	<10	(<0.01)	600	(0.4)	<370	600	(0.4)	-	-
Zn	3,300,000	300	(0.01)	70	(0.002)	7,000	(0.21)	100	7,000	(0.21)	ET	ET
PCB	280,000*	2,200	(0.79)	1,800	(0.64)	30	(0.01)	1	30	(0.01)	IW	IW
Oil/Grease	7,300,000	160,000	(2.19)	-	-	152,000	(2.1)	2,000	150,000	(2.05)	ET	ET
Total P	5,700,000	U 14,000	(0.25)	10,000	(0.18)							
		F 8,000	(0.14)	4,000	(0.07)	10,000	(0.18)	4,000	6,000	(0.11)	ET IW	ET IW
$N\text{-}NH_3$	280,000	110,000	(39.3)	27,000	(9.6)	241,000	(86.1)	1,400	240,000	(85.7)	ET	ET
TKN	6,100,000	160,000	(2.6)	44,000	(0.72)	250,000	(4.1)	5,000	245,000	(4.0)	ET	ET
COD	280,000,000	9,000	(0.003)	1,200	(0.0004)	-	-	-	-	-	-	-

* Value reflects PCB in surface sediment only (approximately 55 gallons)
U Unfiltered
F Filtered
ET Standard Elutriate Test
IW Interstitial Water

Table 17. COMPARISON OF PREDICTIVE TEST ACCURACY

Comparison	Observed Return Flow Values versus				Adjusted Observed Return Flow Values versus			
	Standard Elutriate Test		Interstitial Water Evaluation		Standard Elutriate Test		Interstitial Water Evaluation	
	No.	(%)	No.	(%)	No.	(%)	No.	(%)
Number Parameters With Higher Predicted Values Than Observed	5	(36%)	2	(15%)	7	(50%)	3	(23%)
Number Parameters With Lower Predicted Values Than Observed	6	(43%)	10	(77%)	6	(43%)	9	(69%)
Number of Predicted Values Same as Observed	3	(21%)	1	(8%)	1	(7%)	1	(8%)
Number Parameters With Predicted Value								
(A) Within ± 2X (observed value)	7	(50%)	1	(8%)	4	(29%)	3	(23%)
(B) Within ± 3X (observed value)	9	(64%)	3	(23%)	7	(50%)	4	(31%)
(C) Within ± 10X (observed value)	11	(79%)	9	(69%)	10	(71%)	8	(62%)
(D) Within ± 25X (observed value)	13	(93%)	9	(69%)	12	(86%)	8	(62%)
Total Number of Parameters	14	(100%)	13	(100%)	14	(100%)	13	(100%)

water evaluation" meet this criteria. 64% of pollutants give results that fall within ± three times (±3X) the values using the "Standard Elutriate Test" but only 23% do so for "interstitial water evaluation". The "Standard Elutriate Test" appears to be valid for most metals, grease and oil and nutrients. "Interstitial water evaluation" appears to be useful only for some metals and nutrients. Both tests failed to predict PCB release accurately. Interstitial water evaluation predictive capabilities generally increase when effects due to river water used in the dredging operation are considered (See Table 16).

(5) Microbiological Enumeration

Table 18 lists the bacteriological results from the six stations located in the Slip 1 study area. Samples collected before dredging (pre-dredge) and approximately nine weeks later (post-dredge) showed a significant removal in all bacterial groups, particularly *C. perfringens*. The only area not to show a decrease in *C. perfringens* was area 1 (Figure 3), which happens to be the location of the PCB spill and closest to the main channel of the Duwamish Waterway. Considering this area was dredged to a greater depth (10 feet) than the surrounding areas, backwater currents may have re-deposited sediments from the main channel during the three month interim between the pre and post dredge visits. Samples collected from the main channel 18 months earlier (August 1974) had shown a high background level of *C. perfringens* ranging from 60-35,000 organisms/g.

Besides *C. perfringens*, there was a significant reduction in FC densitites which often indicate the presence of fecal waste material. Since it is known that most enteric bacteria as well as viruses eventually end up in bottom sediments after they are discharged into either fresh or marine waters, determination of public health hazards should include a concern for their presence and removal from bottom sediments.

(B) PHASE II. DREDGE MONITORING ACTIVITIES

(1) Estimation of PCB Removal by Analysis of Slip 1 Sediments

Approximately 86-98% of the spilled Aroclor was removed from Slip 1. Several samples of dredged area sediments were analyzed for PCB contamination while the dredging operation was in progress. Most areas proved to be relatively free of the contaminant after one pass of the dredge (Table 19, Figure 4), but the area near the impact site was redredged several times to achieve maximum removal of the Aroclor. The result of this continual redredging was the formation of a hole approximately

TABLE 18. BACTERIAL CONTENT OF POST AND PRE-DREDGE SEDIMENT SAMPLES TAKEN FROM SIX ZONAL AREAS IN SLIP ONE

Station	Date	Total Coliforms /100 g.	Fecal Coliforms /100 g.	Fecal Strep-tococci /100 g.	20° C Plate Count/g	Clostridium Perfringens/g
	PRE-DREDGE					
1	2/23/76	350,000	7,900	350,000	1,600,000	6,000
2	2/23/76	54,000	7,900	170,000	1,800,000	5,500
3	2/23/76	9,000	1,300	46,000	1,100,000	10,000
4	2/23/76	35,000	790	170,000	1,000,000	11,000
5	2/23/76	4,900	4,900	92,000	1,800,000	15,000
6	2/23/76	54,000	13,000	350,000	3,200,000	8,200
	POST-DREDGE					
1	5/3/76	2,400	2,400	2,800	140,000	17,000
2	5/3/76	18	18	1,400	210,000	400
3	5/3/76	20	18	130	7,600	93
4	5/3/76	4,600	2,400	54,000	620,000	2,700
5	5/3/76	4,600	490	11,000	360,000	790
6	5/3/76	35,000	1,700	92,000	360,000	4,000

Table 19. PCB IN SEDIMENTS TAKEN DURING DREDGING OPERATIONS*

Date	Description	1248/54	1242	Total PCB
3-10-76	Station 231 (30 ft. from pier off riverside ladder)	1.6	2.5	4.1
3-10-76	30 ft. north of Station 231	0.8	3.3	4.1
3-10-76	30 ft. south of Station 231	1.8	2.3	4.1
3-15-76	20 ft. northeast of Station 226	2.7	1.2	2.9
3-15-76	100 ft. south of Station 225	1.4	0.9	2.3
3-15-76	Station 224	1.1	1.1	2.2
3-22-76	70 ft. southwest of northeast corner of Slip 1	0.4	<0.1	0.4
3-22-76	30 ft. west of Station 227	1.8	1.1	2.9
3-22-76	Station 225 off pier side ladder (north side of Slip 1 entrance)	-	2,400	2,400
3-23-76	Composite of four grabs taken (1) at Station 225 (2) 25 ft. east of 225 (3) 25 ft. west of 225 and (4) 25 ft. south of 225	-	112	112
3-26-76	25 ft. south of Station 225	-	184	184
3-26-76	Composite of three grabs taken (1) at Station 225 (2) 25 ft. east of 225 and (3) 25 ft. west of 225	-	16	16
3-27-76	30 ft. south and 30 ft. west of Station 225	-	13	13

TABLE 19 (Continued)

3-27-76	30 ft. south of Station 225	-	43	43
3-27-76	30 ft. south and 30 ft. east of Station 225	-	41	41
3-29-76	30 ft. south of Station 225	-	17	17
3-29-76	30 ft. south and 30 ft. east of Station 225	0.5	0.3	0.8

* Results expressed in microgram/gram, wet weight (ppm)

60' X 30' X 10' deep. The concentration of PCB in sediment varied over a wide range. It can be shown that approximately 100 gallons of Aroclor 1242 were removed with the sediment in this area if one assumes the average PCB concentration was 760 ppm. This concentration (760 ppm) is reasonable if one considers the levels of PCB contamination encountered during the redredging process. Most of the impact area sediment was removed before March 23, 1976 during one day of dredging. The remaining material was removed using a dredge operating at one third capacity over a two day period. The ratio of volumes of sediment dredged during these time periods may be calculated by comparing the number of days of dredging activity for each time period adjusted to account for differences in dredge capacity during the same time periods (See Equation A). Therefore, (1.0 day) (1.0):(2.0 day) (0.33) becomes 60% sediment volume: 40% sediment volume for the two time periods.

Eqn. A. (Days)(cap.):(Days)(Cap.)

Values of PCB between 112 to 2400 ppm were encountered at the impact area during removal of the first 60% of the sediment and between 0.8 and 43 ppm for the remainder. If an average value of 1,256 ppm of PCB is used for the first 60% of the volume of sediment removed from the area and 22 ppm for the remaining 40%, then one arrives at the overall average of approximately 760 ppm PCB in the sediment. Since the sediment density was 85 lbs/ft.^{3}, it follows that approximately 100 gallons of PCB were removed with the sediment (See Equation B).

Eqn. B. Amount of PCB recovered from impacted area

$$\frac{760 \text{ X } 10^{-6} \text{ lb. PCB}}{\text{lb. sed.}} \quad \frac{85 \text{ lb. sed.}}{\text{ft.}^3 \text{ sed.}} \quad \frac{10\text{X}30\text{X}60 \text{ ft.}^3}{1} \quad \frac{1 \text{ gal. PCB}}{11.5 \text{ lb. PCB}}$$

= 101 gallons

An estimate of the amount of PCB removed from the remaining area of the slip was made by difference. In an internal memo to F. Nelson, Chief of EPA Technical Support Branch, J. N. Blazevich calculated the amount of PCB in Slip 1 (minus that in the impact area) to be approximately 40 gallons on November 4, 1974 (2). Assuming all 40 gallons were removed from the remaining portion of the slip, the amount of PCB recovered by the second cleanup operation would be 140 gallons. When added to the 80 gallons removed during the first clean-up effort (1), the total amount of PCB recovered becomes approximately 220 gallons.

(2) Disposal Pond Influent

Disposal pond influents were collected and analyzed for several pollutants (See Appendix C, Sections II, V and VI for results). Analysis of the data will be made in detail by Mr. Ron Hoeppel of the Army Corps of Engineers, Waterways Experiment Station at Vicksburg, Mississippi.

(3) Disposal Pond Effluent

Unfiltered disposal pond effluents were monitored during the dredging operation. Estimates of quantities of various pollutants returning to the river based on the number of gallons of return water and the concentration of pollutant present in representative composite samples are found in Table 16. (See Appendix C, Section II and Appendix D, Table D-7). See Part IVA, Phase I (4) for discussion. Filtered disposal pond effluents were monitored to determine the amount of PCB returning to the river (See Table 20). Less than 11 grams of PCB were found in the effluent.

(4) Water Column at the Dredge Site

Analysis of water collected at the dredge site was performed. Comparison of background and dredge site monitoring station data indicate little, if any, increase in pollutants in the water column at Slip 1 during the dredging activities, except for a transient PCB pulse that was observed in samples collected almost exclusively in the dredge vehicle prop wash while work in the area of highest PCB concentrations was in progress. The results are reported in Appendix C, Section IV.

(5) Miscellaneous Results

Several other samples of water and sediment were analyzed during the course of the dredging operation (See Table 21). These analyses were performed to help determine the impact of the dredging project on the environment.

Water samples from several points within the disposal treatment process were analyzed for PCB's in order to determine if the facility was working as designed. Some points (i.e. effluent from Pond 1) were monitored regularly for metals, nutrients and PCB's (See Appendix C, Section II).

Samples of sediment and solids from influent and effluent were used to determine the amount of easily reduced metals, etc., present in each. These data are found in Appendix C, Section V.

Table 20. PCB IN EFFLUENT FROM FILTER SYSTEM*

Date of Sampling	Gallons Pumped ⁑	1248/54	1242	Grams PCB Discharged into Duwamish
3-13-76	100,000	-	<0.5	<0.2
3-14-76	45,000	-	<2.4	<0.4
3-14-76	48,000	0.3	<0.01	0.05
3-15-76	65,000		Lost	-
3-16-76	115,000	0.7	0.04	0.05
3-16-76	108,000	<0.05	<0.05	<0.04
3-17-76	120,000	<0.05	<0.05	<0.05
3-17-76	48,000	<0.1	<0.1	<0.04
3-17-76	25,000	<0.1	<0.1	<0.02
3-18-76	46,000	0.06	<0.02	0.01
3-18-76	3 carbon column	0.05	<0.02	-
3-18-76	in parallel	0.07	<0.02	-
3-20-76	169,000	<0.05	<0.05	<0.06
3-20-76	66,000	<0.08	<0.08	<0.04
3-21-76	230,000	<0.05	<0.05	<0.09
3-21-76	300,000	<0.05	<0.05	<0.11
3-22-76	216,000	<0.05	<0.05	<0.08
3-23-76	543,000	<0.05	<0.05	<0.2
3-24-76	432,000	<0.1	<0.1	<0.3
3-25-76	432,000	0.33	0.36	1.1
3-26-76	432,000	0.25	0.24	0.8
3-27-76	432,000	0.35	0.18	0.9
3-28-76	828,000	0.16	0.18	1.1
3-29-76	624,000	1.1	<0.1	2.6
3-30-76	408,000	0.07	0.04	0.2
3-31-76	696,000	0.03	0.05	0.2
4-1-76	504,000	0.08	0.06	0.3
4-2-76	678,000	0.03	0.05	0.2
4-3-76	810,000	<0.16	0.06	<0.7
4-4-76	378,000	0.22	<0.01	0.3
4-6-76	432,000	<0.01	<0.01	<0.03
4-7-76	504,000	0.1	0.01	0.2
Total	9,834,000			<11 g

* Results expressed in microgram/liter
⁑ Measured flow values

Table 21. PCB RESULTS FOR MISCELLANEOUS SAMPLES*

Date	Description	1248/54	1242	Total PCB
3-12-76	Effluent from pond 1 to pond 2	< 0.05	2.1	2.1
3-16-76	Effluent from carbon filter 1	< 0.01	< 0.01	< 0.01
3-16-76	Pond 3 water (after Corp filter)	< 0.01	< 0.01	< 0.01
3-17-76	Material from EPA mixed media filters	< 3	< 3	< 3 ‡
3-19-76	Grab water from pond 1	< 0.09	< 0.05	< 0.09
3-19-76	Grab water from pond 2	< 0.05	< 0.05	< 0.05
3-17-76	Fish from hatchery	< 0.02	< 0.02	< 0.02
3-30-76	Sediment off diagonal STP outfall	0.435	< 0.070	0.435 ‡
4-3-76	Effluent from pond 1 to pond 2 (15607)	0.30	0.90	1.2
4-2-76	Centrifuged water of 15607	0.14	0.34	0.48
4-4-76	Effluent from pond 1 to pond 2 (15613)	0.3	1.3	1.6
4-4-76	Centrifuged water from 15613	0.14	0.25	0.39
4-4-76	Composite of pond 3 (after Corp filter)	0.32	0.17	0.49
4-5-76	Effluent pond 1 to pond 2 (15622)	7.3	5.0	12.3
4-5-76	Centrifuged water from 15622	0.58	1.1	1.7

TABLE 21 (Continued)

4-7-76	Composite pond 3 (before Corps filter)	0.16	0.19	0.35
4-7-76	Solids from high speed centrifugation of pond 2 effluent	NA	NA	NA

* Results expressed in microgram/liter, except where noted
⸸ Results expressed in microgram/gram, wet weight (ppm)
NA Not Available

(6) Microbiological Enumeration

The results of bacteriological monitoring during the actual dredging operation are shown on Table 22. With the exception of TC's, all bacterial indices were reduced by passage through disposal ponds 1 and 2. Many microorganisms found in sediments are bound to solids or occur as aggregates adsorbed to solids and simply settle out in slow moving or static water systems. The survival and movement of microorganisms adsorbed to solids are quite variable and influenced by such environmental conditions as pH, temperature, antagonisms, nutrient availability, etc. Furthermore, sporeforms such as *C. perfringens* and certain cocci such as FS survive better in sediment environments than either TC or FC and consequently may be more associated with dredge materials. This combination of factors may have been responsible for the great reduction in the FS and *C. perfringens* population as opposed to the corresponding TC and FC populations.

(C) PHASE III. POST-DREDGE

Post-dredge monitoring activities, including analysis of river bottom sediments, disposal pond sludges and stratified dredge site water column samples, were conducted in order to assess the effectiveness of the recovery effort and the environmental effects of the project.

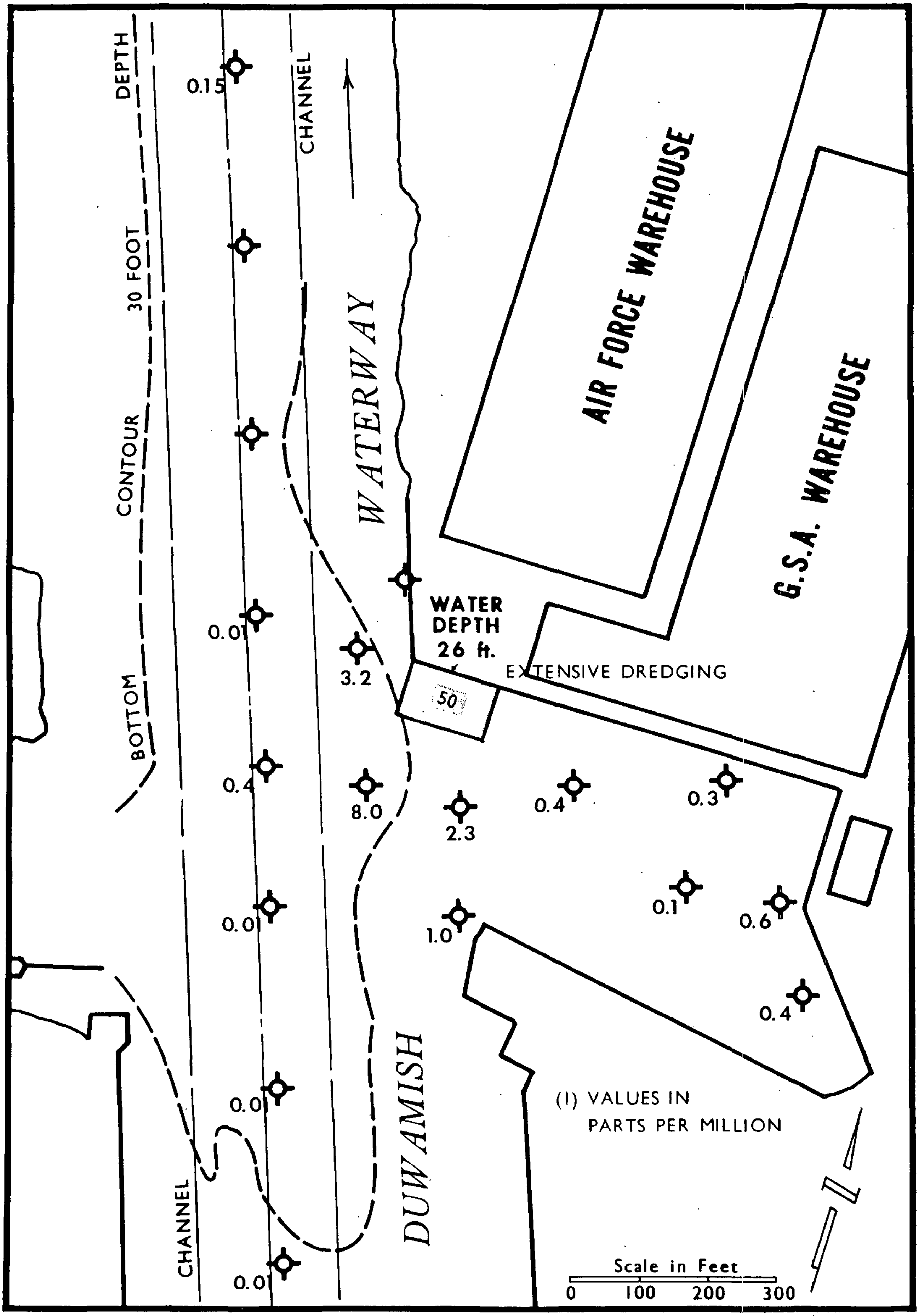
(1) Slip 1 Sediments

A post-dredge survey of Slip 1 and river channel sediments was made on May 4, 1976. Evaluation of survey results indicates that a large portion of the slip is free of Aroclor 1242 (See Table 23, Figure 19). Only the area in the impact site shows elevated Aroclor 1242 levels in the sediment. When compared to the higher levels observed during the second clean up effort (2400 ppm) (See Table 19), one notes a 50 fold reduction of the pollutant. The impact area was sampled twice using two different sampling methods. The first method required use of the top 5 cm of sediment to determine the extent of translocation and dilution of PCB contaminated sediment. The second method required compositing of several grab samples in order to formulate a more accurate description of the PCB burden in the impact area. Of course, localized effects are minimized using the latter method.

Analyses of other pollutants in sediments and interstitial water were performed. The results are tabulated in Appendix C, Section III.

TABLE 22. BACTERIAL CONTENT OF INFLUENT INTO DISPOSAL POND 1 AND EFFLUENT OUT OF DISPOSAL POND 2.

Location	Date	Dredge Area	Total Coliforms/ 100 ml.	Fecal Coliforms/ 100 ml.	Fecal Strep-tococci /100 ml.	20^{o} C Plate Count /ml.	Clos-tridium per-fringens /ml.
Influent to Pond No. 1	3/16/77	5 & 6	220	220	2,400	44,000	3,000
	3/22/76	3	790	40	330	7,900	690
	3/23/76	1	14,000	490	2,400	35,000	370
	3/30/76	1	220	18	170	4,000	88
	4/5/76	1	49	18	18	19,000	2
Effluent from Pond No. 2	3/16/77	5 & 6	920	18	18	14,000	10
	3/22/76	3	2,800	18	18	22,000	1
	3/23/76	1	7,900	18	18	3,000	7
	3/23/76	1	1,400	18	18	9,100	2
	3/30/76	1	68	18	18	19,000	2



PCB SEDIMENT CONCENTRATION (POST DREDGE)

MAY 4, 1976

FIGURE 19

Table 23

RESULTS OF ANALYSIS OF PCB'S IN DUWAMISH RIVER POST DREDGE SURVEY (5-4-76)*

Station Number	1248/54	1242	Total PCB
211	0.2	0.05	0.2
212	0.2	0.03	0.2
213	0.2	0.09	0.3
214	0.3	0.15	0.4
202	0.4	<0.01	0.4
203	0.3	<0.01	0.3
204	0.2	<0.01	0.2
206	0.2	<0.01	0.2
207	0.2	<0.01	0.2
208	0.2	<0.01	0.2
209	0.2	<0.01	0.2
218	0.5	3.2	3.7
219	0.3	<0.01	0.3
222	0.4	0.4	0.8
223	-	8	8
224	0.5	2.3	2.8
225	-	140	140
226	0.4	0.4	0.8
227	1.4	0.3	1.7
228	1.5	0.1	1.5
229	0.5	0.4	0.9
230	0.6	1.0	1.6
232	0.3	0.1	0.4
233	0.2	0.1	0.3
250	<0.6	<0.6	<0.6
Composite of area in and around 225	-	50	50
Blanks	<0.01	<0.01	<0.01

* Results expressed in microgram/gram, wet weight (ppm)

(2) Estimation of PCB Removal by Analysis of Disposal Pond Sediments

An attempt was made to determine the amount of PCB trapped in the first disposal pond. Analysis of nine composite samples consisting of 166 separate grab samples and a land survey of the spoils were used to estimate the amount of PCB removed from Slip 1 (See Figures 5 & 6). Since the BIA ship, the Northstar, was berthed near the impact area during the first half of the operation, only a portion of the highly contaminated sediments were initially dredged. The dredge was returned to the impact site after working in a less polluted area only after the Northstar was moved. Surface and total core samples were composited in an attempt to detect stratification of highly polluted sediments due to the order in which sediments were dredged. [redacted] Therefore, averages of PCB values from two areas in Pond 1, area 1 (146 ppm) and areas 2 and 3 (33 ppm), were used along with [redacted] to calculate the amount of PCB (170 gallons) in the disposal pond sediments (See Appendix E, Figure E-1). When added to the 80 gallons removed during the first clean up, the total amount of PCB recovered becomes 250 gallons or a 98% recovery.

(3) Water Column at the Dredge Site

Evaluation of water column data (See Appendix C, Section 4) indicates no measurable amount of pollutants were introduced into the water column at the dredge site by the dredge operation.

(4) Microbiological Enumeration

The dredge spoils sampled from the first disposal pond are shown in Table 25. Except for the SW corner, all five bacterial indices appear well dispersed throughout the entire area of the pond. Since the SW corner was the location of the outlet pipe from the dredge, it is not surprising to find higher numbers of most parameters at this location.

FC populations in the pond were low while the FS and 20° C plate counts were quite high. This disparity in numbers could be attributed to the relative survivability of each in dry sediments lacking a complete water cover. Surprisingly, only the S.E. transect and S.W. corner contained high residual levels of *C. perfringens*. The adaptability of this sporeforming organism to harsh environments is well documented (18) as is it's association with organic material originating from treated human sewage waste. This organism is perhaps the most widely spread pathogenic bacterium in the Puget Sound and directly relates to the amount of pollution present (19).

Table 24. RESULTS OF ANALYSIS OF POND 1 DREDGE SPOILS*

Sample Number	Description	[redacted]
23400	Whole core - southeast transect	[redacted]
23401	Surface - southeast transect	[redacted]
23402	Whole core - middle transect	[redacted]
23403	Surface - middle transect	[redacted]
23404	Whole core - west transect	[redacted]
23405	Surface - west transect	[redacted]
23406	Whole core - northeast section	[redacted]
23407	Surface - northeast section	[redacted]
23408	Surface - southwest corner	[redacted]

* Expressed in microgram/gram, wet weight (ppm)

TABLE 25. DREDGE SPOILS COLLECTED FROM DISPOSAL POND #1 APPROXIMATELY TWO MONTHS AFTER DREDGE OPERATION

Location	Type of Sample	Total Coliforms /100g	Fecal Coliforms /100g	Fecal Strep-tococci /100g	20^{o} C Plate Count/g	Clos-tridium per-fringens/g
S.E. Transect	Hold Core	270	18	4,600	3,800,000	2,200
Middle Transect	Hold Core	7,900	20	2,100	2,200,000	10
West Transect	Hold Core	490	20	1,700	1,600,000	10
N.E. Section	Hold Core	78	18	790	210,000	10
N.E. Section	Surface Grab	230	20	1,300	11,000,000	11
S.W. Corner	Surface Grab	79,000	18	1,400	15,000,000	4,000

REFERENCES

(1) Region X On-Scene Coordinator Report. PCB, Duwamish Waterway, Seattle, WA, September 13-October 31, 1974.

(2) Blazevich, J. N., memo to F. Nelson, U. S. Environmental Protection Agency, Region X. February 10, 1975.

(3) Pavlou, S. et. al. University of Washington Special Report No. 66. PCB Monitoring in the Duwamish River, A Study of Their Release Induced by the Dredging Activities in Slip 1. July 1976.

(4) U. S. Environmental Protection Agency, Ocean Dumping Final Criteria, Federal Register 38 (94), 12872-12877, 1973.

(5) U. S. Environmental Protection Agency, Ocean Dumping Final Criteria, Federal Register 38 (198), 28610-28621, 1973.

(6) Keeley, J. W. and R. M. Engler. Discussion of Regulatory Criteria for Ocean Disposal of Dredged Materials Elutriate Test Rationale and Implementation Guidelines. U. S. Army Waterways Experiment Station Misc. Paper D-74-14, 13 p., 1974.

(7) Elutriate Test Implementation Guidelines, Ocean Dumping Criteria for Dredged Material. ER 1130-2-408, Jan. 17, 1974. Department of the Army, Office of the Chief of Engineers, Washington, D.C. 20314.

(8) Recommended Procedures for the Bacteriological Examination of Sea Water and Shellfish. 4th Ed., American Public Health Association, American Public Health Association, New York, N.Y., 1970.

(9) Standard Methods for the Examination of Water and Wastewater. 14th Ed., American Public Health Association, 1015 Eighteenth St., N.W., Washington, D.C., 1975.

(10) Methods for Chemical Analysis of Water and Wastes, EPA Office of Technology Transfer, Washington, D.C. 20460. 1974.

(11) Analytical Methods for Atomic Absorption Spectrophotometry, Perkin-Elmer, Norwalk, Connecticut 06856. 1976.

(12) Krishnamurty, K. V., E. Shpirt, and M. M. Reddy, Atomic Absorption Newsletter, 15, (3), 68, 1976.

(13) Analysis of Pesticide Residues in Human and Environmental Samples. U. S. Environmental Protection Agency. J. F. Thompson, Editor. Research Triangle Park, N. C. 1974.

(14) Determination of Pesticide and PCB in Sediments, U. S. Environmental Protection Agency, Region X Laboratory, 1975.

(15) Green, E. J. and D. Schnitker. Marine Chemistry, 2, 111, 1974.

(16) Bacteriological Analytical Manual. U. S. Food and Drug Administration, Washington, D.C., 1972.

(17) Sound Survey Photo Maps of Duwamish River. U. S. Army Engineers Seattle District, File No. E-12-2.1-70 and E12-2.1-71, U. S. Army Corps of Engineers, 1973, 1974.

(18) Bonde, G. J. Pollution of a Marine Environment. J. Water Pollution Cont. Fed. 39, 45-63, 1967.

(19) Matches, Jack R., John Liston and Donald Curran. Clostridium perfringens in the Environment. Appl. Microbiol. 28, 655-660, 1974.

Appendix A

Appendix A

Scope: The monitoring program was carried out in three phases. Phase I included monitoring activities before dredging, Phase II during dredging and Phase III after dredging.

I. Phase I: Predredge Analysis

A. Sediment evaluation was performed before dredging to determine the extent of pollution in Slip 1.

1. Slip 1 Sediments

(a) PCBs in 29 grab samples and 6 composite samples
(b) Metals: Hg, Cd, Pb, Zn, Fe, Mn, Cr, As and Cu in 6 composite samples
(c) Oil and grease and COD in 6 composite samples
(d) Sulfide ion and volatile solids, in 6 composite samples
(e) Nutrients: P, NH_3, and TKN in 6 composite samples
(f) Microbiology: TC, FC, FS and *Clostridium perfringens* (anaerobe)

2. Interstitial Water

(a) PCBs in 6 composite samples
(b) Metals: Hg, Cd, Zn, Fe, Mn, Cr, Ni, As and Cu in 6 composite samples
(c) Nutrients: P, NH_3, NO_3, TKN and TOC in 6 composite samples
(d) pH and conductivity in 6 composite samples

3. Elutriate Test Water with Slip 1 Sediments

(a) PCBs in 6 composite samples
(b) Metals: Hg, Cd, Zn, Fe, Mn, As, Cr, Ni and Cu in 6 composite samples
(c) Oil and grease in 6 composite samples
(d) Nutrients: P, NH_3, NO_3, TKN and TOC in 6 composite samples

4. <u>On Site Monitoring of Interfacial Water Quality at Time of Sediment Collection</u>

   (a) Hydrolab: pH, DO, conductivity, and temperature at each station in or near Slip 1

B. Water Evaluation

1. <u>Suspended Particulate Matter (SPM)</u>

   (a) PCBs were determined in six composite samples collected during the large ebb of the semi-diurnal tide. One set of samples, consisting of a surface and two eight meter deep composites, was acquired over the three hour period just prior to slack water. Another set was obtained in a similar manner during the three hour period immediately after the flood crest.

2. <u>Whole Water</u>

   (a) PCBs were determined in six composite samples collected at depth and time intervals described in IB1a.
   (b) Metals: Water samples were composited according to the scheme outlined in IB1a for determination of Hg, Cd, Zn, Fe, Mn, As, Cr and Cu.
   (c) Nutrients: P, NH_3, NO_3, TKN and TOC were determined in six composites collected in a manner similar to IB1a.
   (d) Oil and grease and sulfide determinations were performed on six samples collected at the center of each sampling interval described in IB1a.

3. <u>On Site Determinations</u>

   (a) Hydrolab: DO, pH, conductivity and temperature were monitored continuously during sample collection.

II. Phase II: Analysis During Dredging Operation

A. Sediment Evaluation

1. <u>Sediments</u>

   (a) PCBs were determined in sediment samples taken from dredged areas in order to estimate the relative success of the dredging operation.

B. Water Evaluation: Dispòsal Pond Influent and Effluent

1. <u>Whole Water</u>

   (a) PCBs were determined in several samples of disposal pond effluent composited daily according to time and volume.

(b) Metals: Hg, Cd, Zn, Fe, Mn, As and Cu were determined in samples composited automatically using an ISCO sampler.

(c) Nutrients: P, NH_3, NO_3, TKN, and TOC were determined in composite samples collected in a manner similar to that used in IIB1b.

(d) Oil and grease and suspended solids were determined in composite samples collected according to the method used in IIB1a.

(e) Microbiology: TC, FC, FS and C. perfringens (anaerobe).

2. On Site Monitoring

(a) Hydrolab: The pH, conductivity, DO and temperature of disposal pond effluent were monitored continuously during the dredging operation.

C. Water Evaluation: River Water at the Dredge Site

1. Suspended Particulate Matter

(a) PCBs were determined according to IB1a.

2. Whole Water

(a) PCBs were analyzed according to IB2a.
(b) Metals as per IB2b.
(c) Nutrients as per IB2c.
(d) Oil and Grease, Sulfide, TKN and TOC according to IB2d.

3. On Site Determinations

(a) Hydrolab as per IB3a.

III. Phase III. Post Dredge Evaluation

A. Sediment Evaluation: Slip 1

Evaluation of Slip 1 sediments was performed after termination of dredging in order to determine the efficiency of the dredging operation and the extent of pollutant translocation.

1. River Bottom Sediments:

Determination of PCBs, metals, etc. was made according to IA1.

2. Interstitial Water: PCB metals, etc. were determined according to IA2.

B. Sediment Evaluation: Disposal Ponds

1. Disposal Pond 1

(a) Determination of PCBs in disposal Pond 1 sediments was made in order to estimate the amount of PCB in that pond
(b) Microbiology; TC, FC, FS and C. perfringens

2. Disposal Pond 2: Since Pond 2 received less than one percent of the total dredge spoil sediment, no evaluation of its sediments was attempted.

C. Water Evaluation: River Water at Dredge Site

1. Suspended Particulate Matter

(a) PCBs were determined according to IB1a

2. Whole Water

(a) All parameters were determined as in IB2.

3. On Site Determinations

(a) Hydrolab as per IB3a.

APPENDIX B

FIGURE B-1

Figures B-2, B-3 and B-4 Combined

RECONSTRUCTED GAS CHROMATOGRAMS

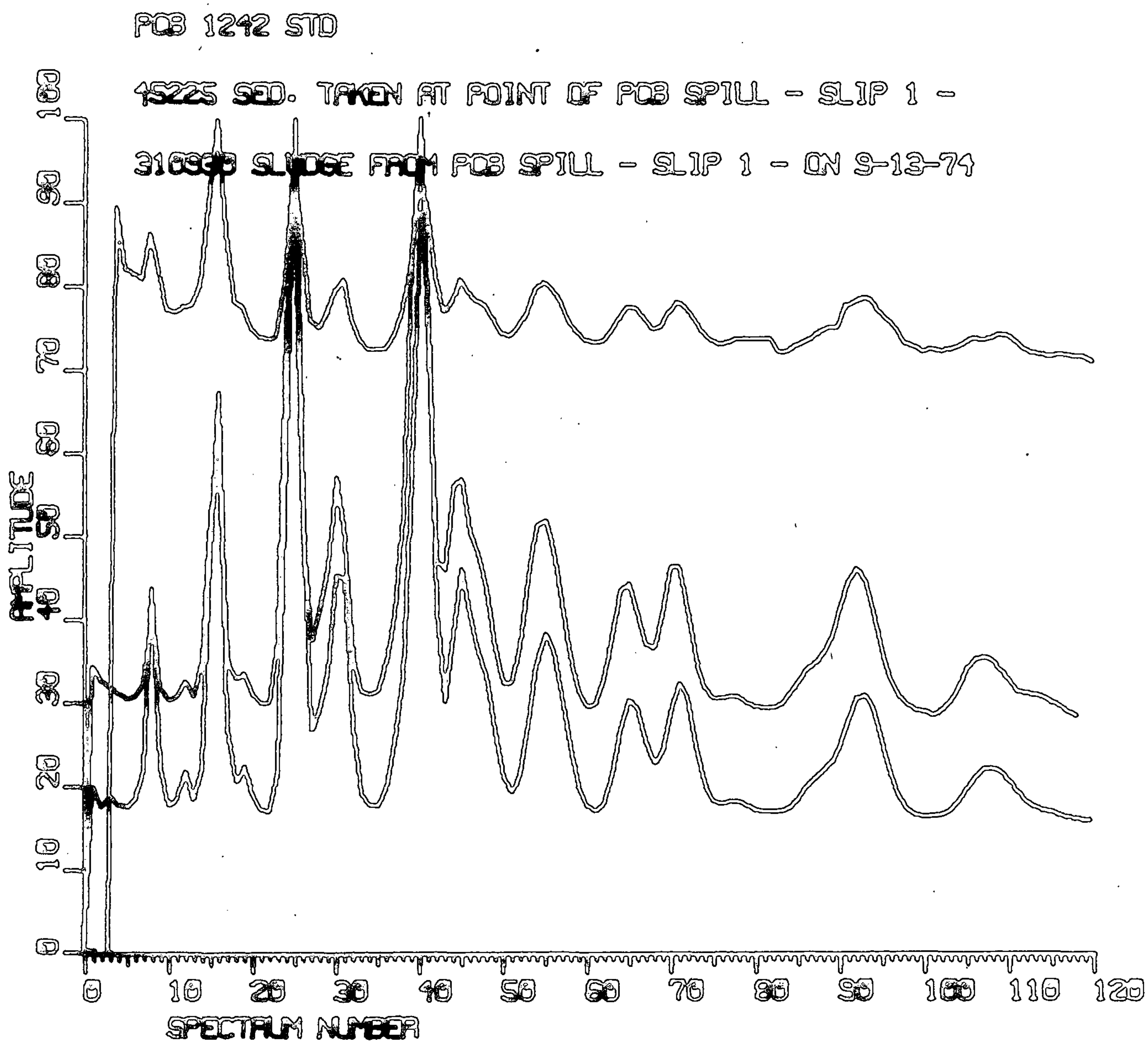


FIGURE B-2

RECONSTRUCTED GAS CHROMATOGRAM

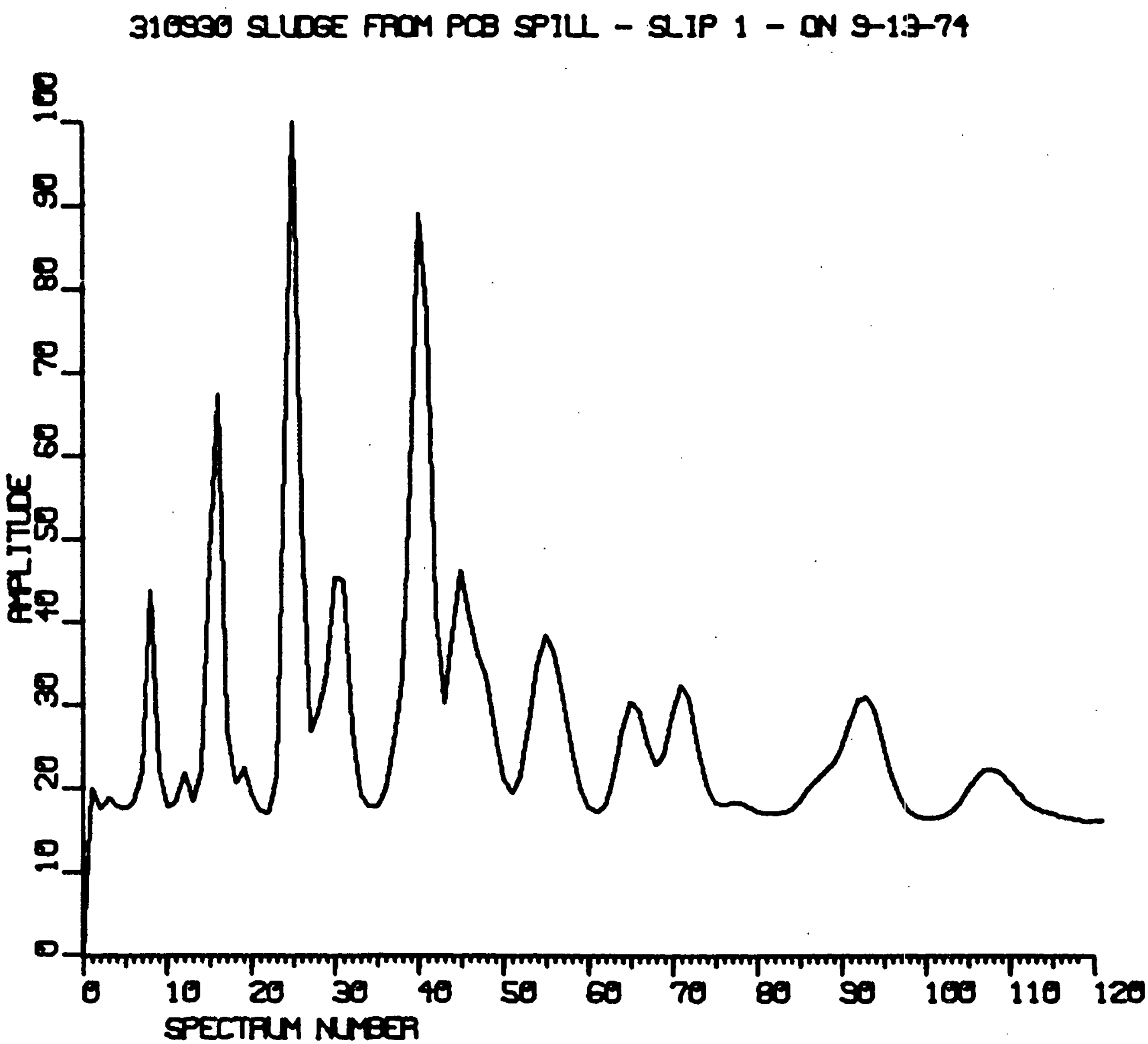


FIGURE B-3

RECONSTRUCTED GAS CHROMATOGRAM

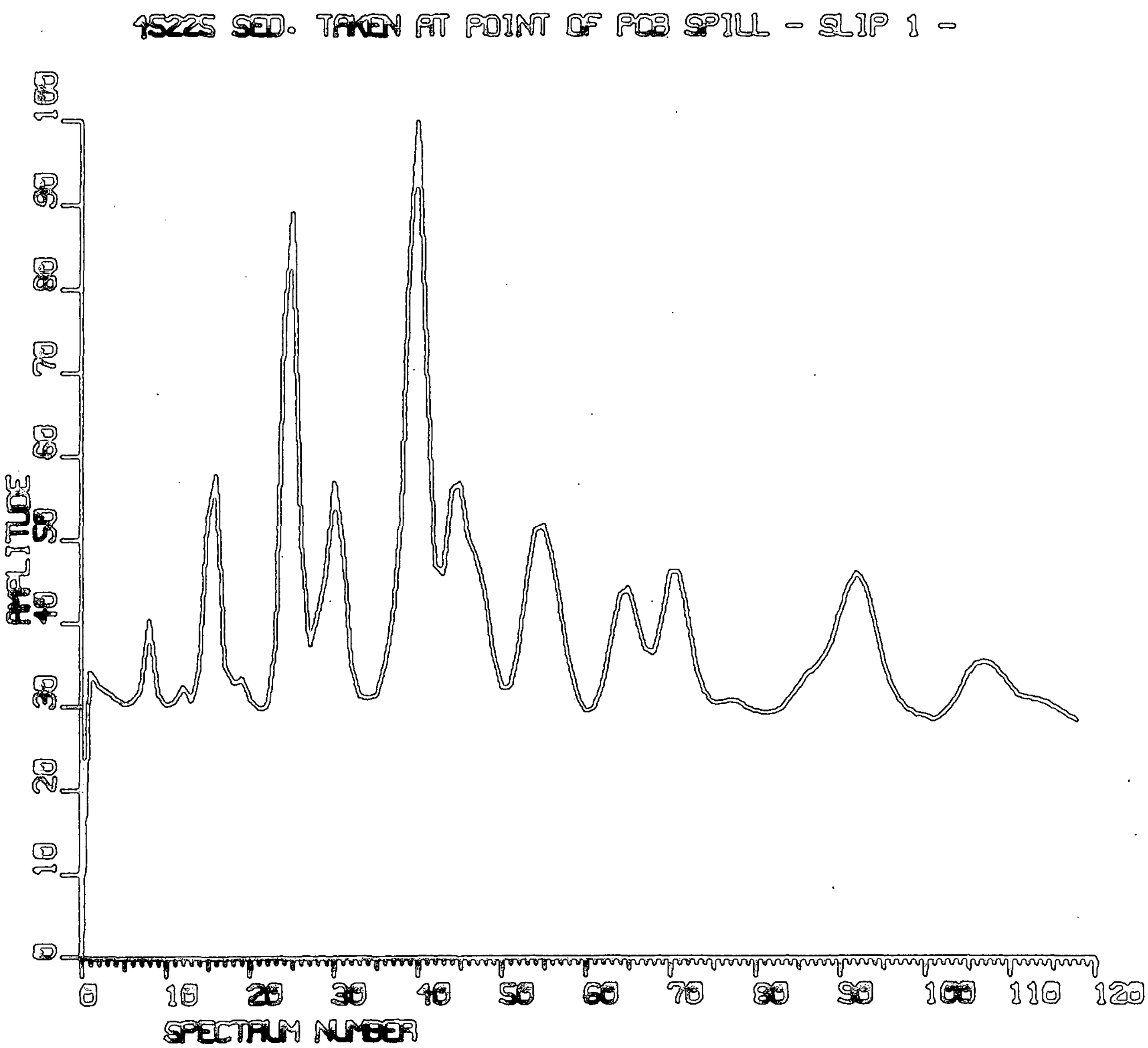


FIGURE B-4

RECONSTRUCTED GAS CHROMATOGRAM

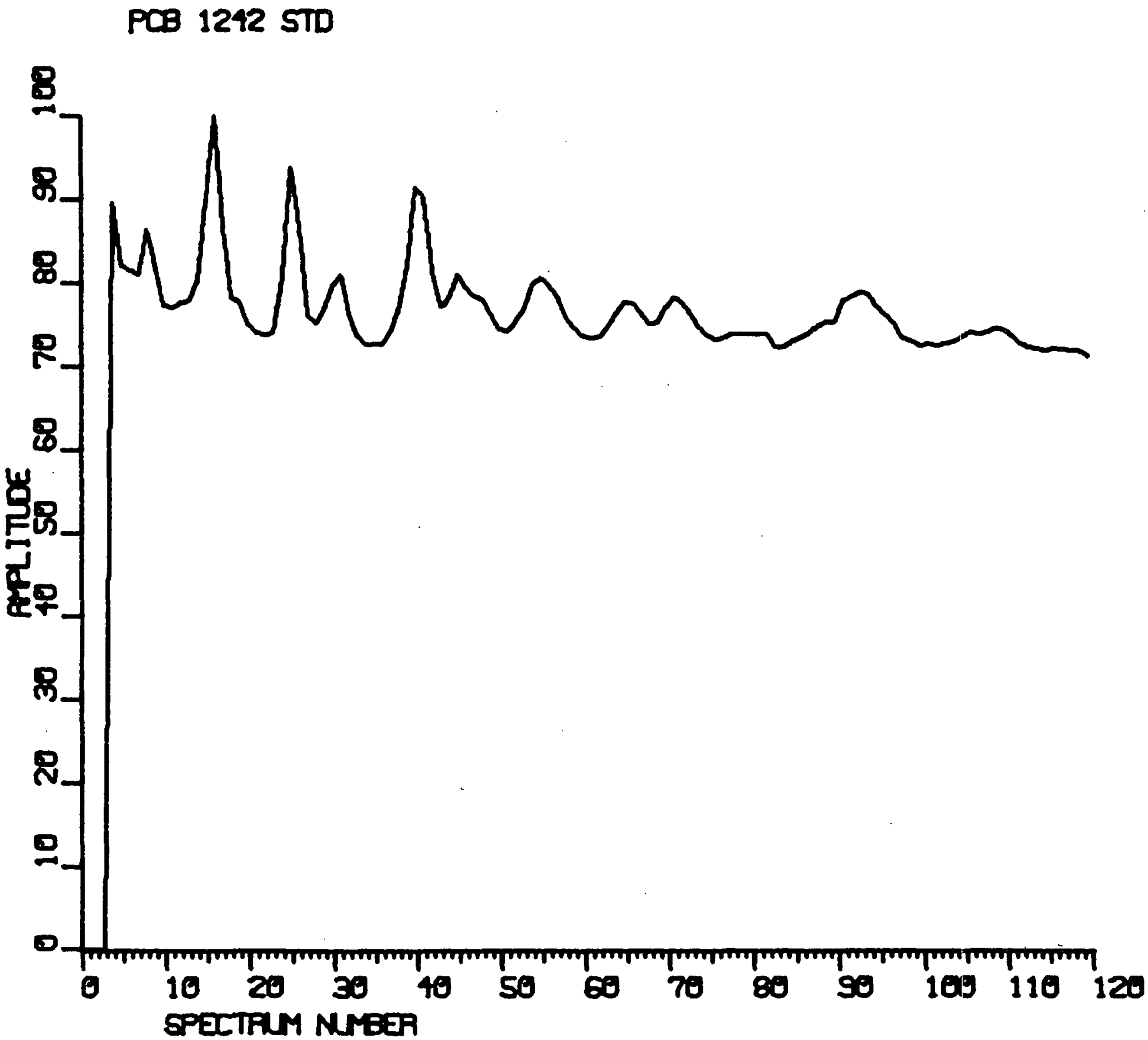


Figure B-5

Figures B-6, B-7 and B-8 Combined
RECONSTRUCTED GAS CHROMATOGRAMS
MASS RANGE: 256-261

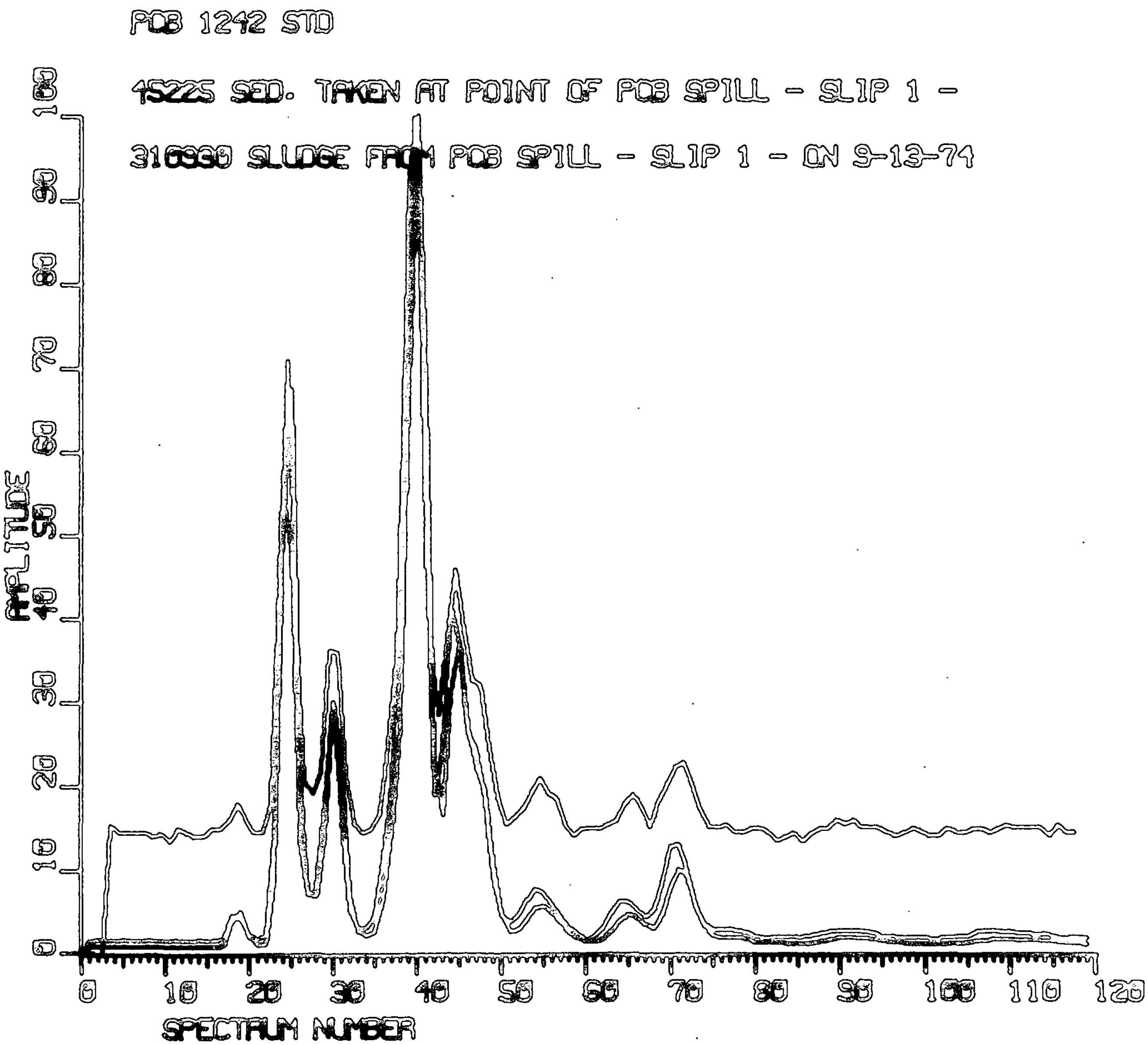


FIGURE B-6

RECONSTRUCTED GAS CHROMATOGRAM
MASS RANGE: 256-261

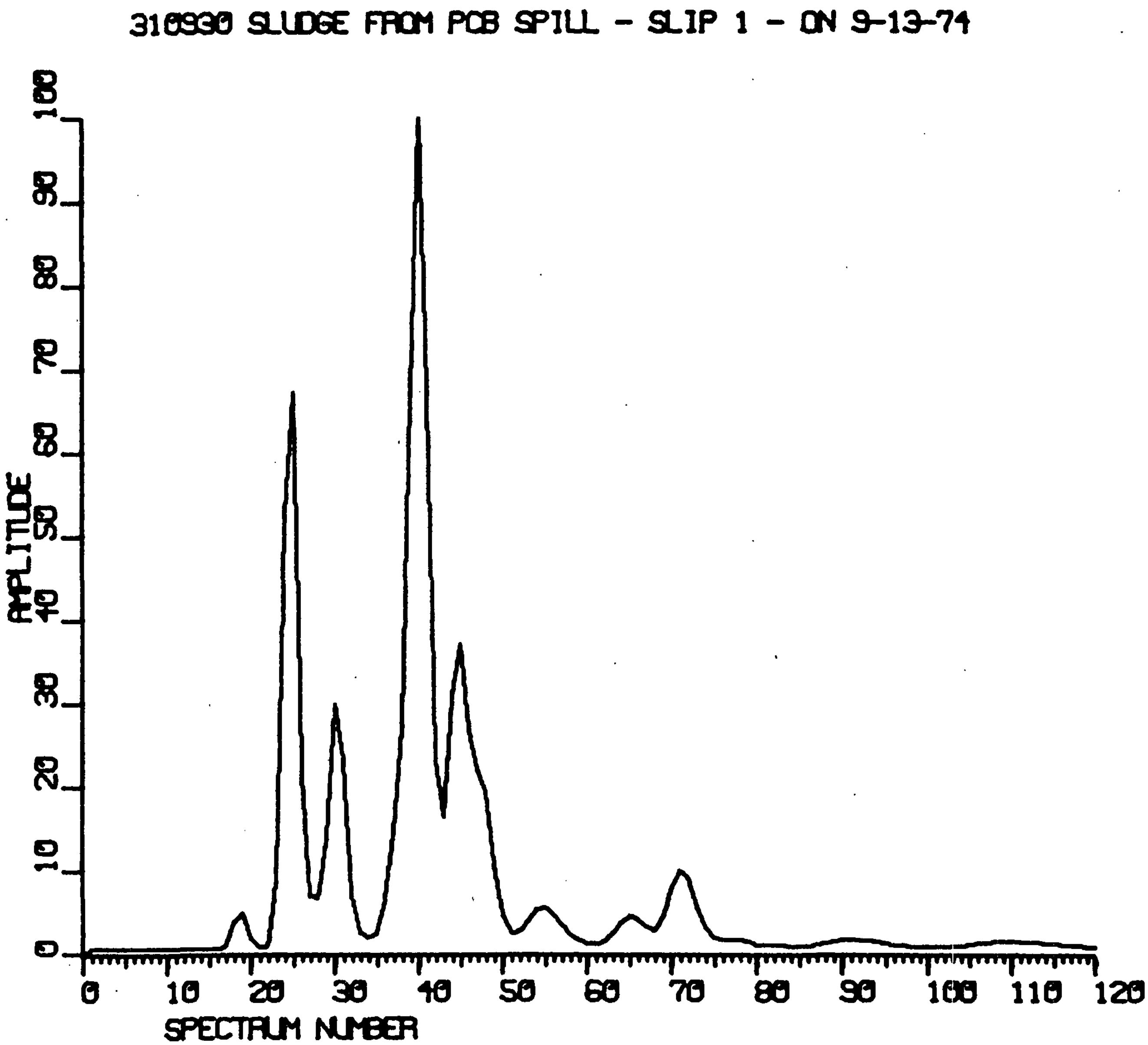


FIGURE B-7

RECONSTRUCTED GAS CHROMATOGRAM
MASS RANGE: 256-261

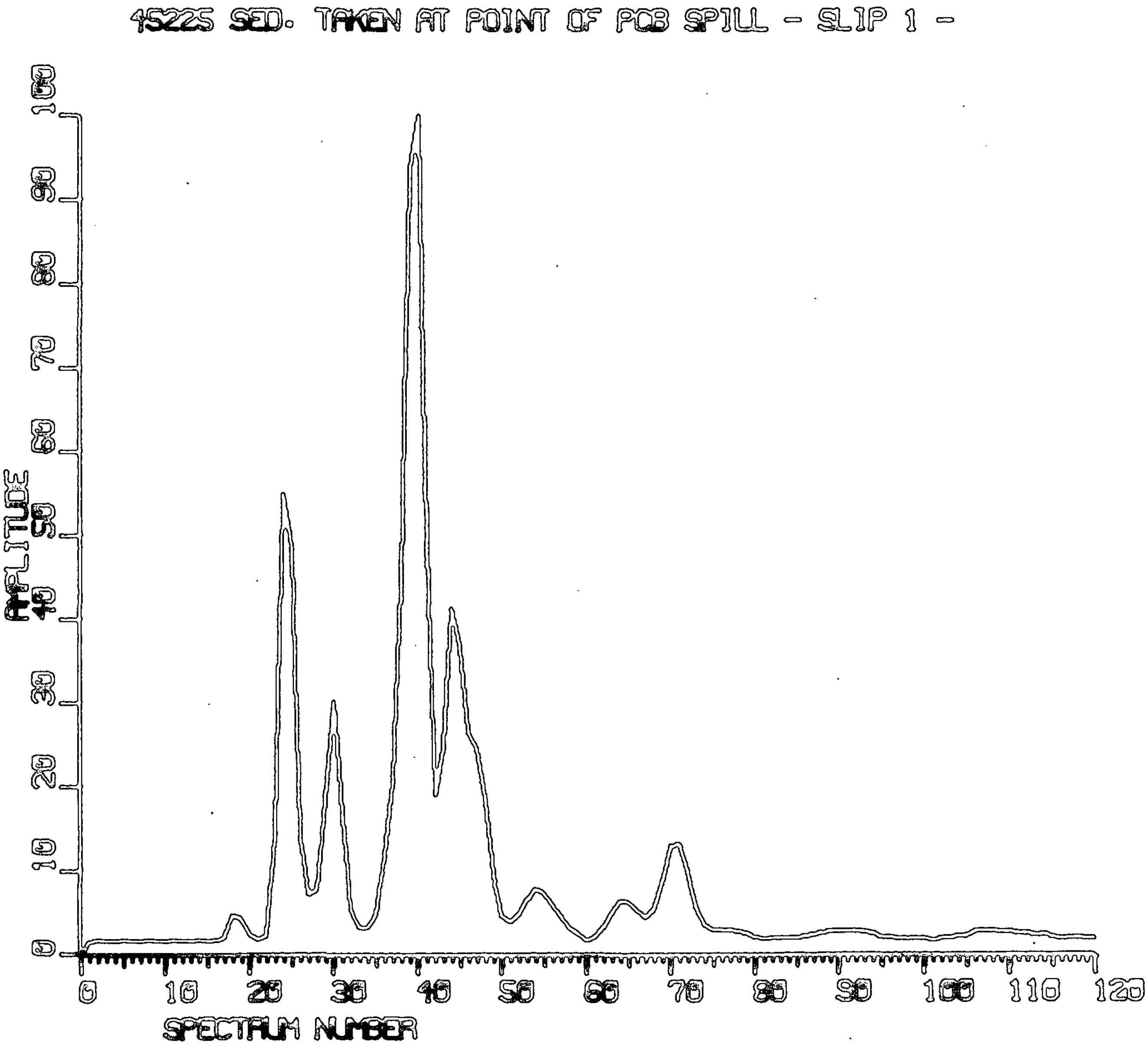


FIGURE B-8

RECONSTRUCTED GAS CHROMATOGRAM
MASS RANGE: 256-261

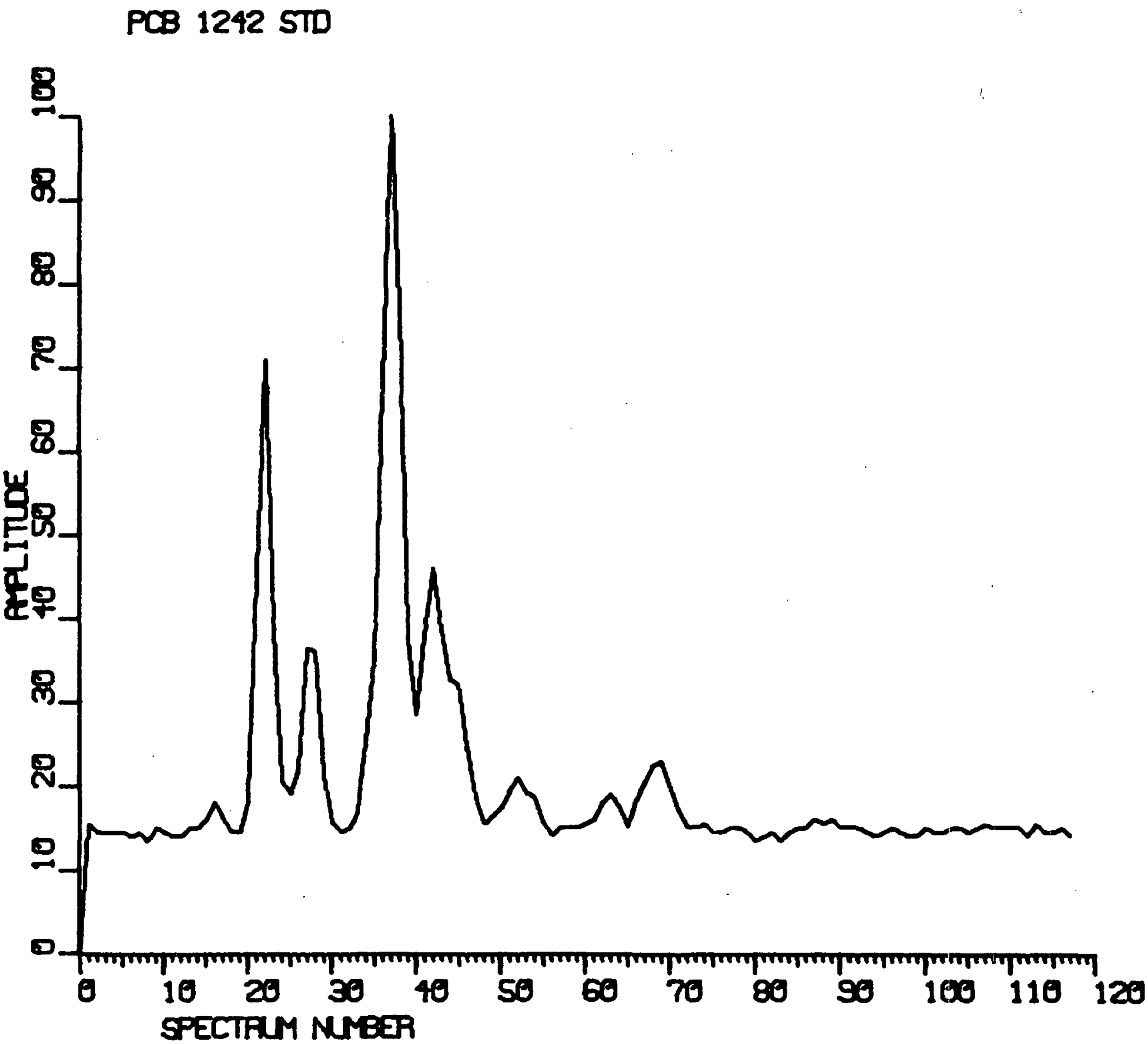


FIGURE B-9

Figures B-10, B-11 and B-12 Combined
RECONSTRUCTED GAS CHROMATOGRAMS
MASS RANGE: 290-300

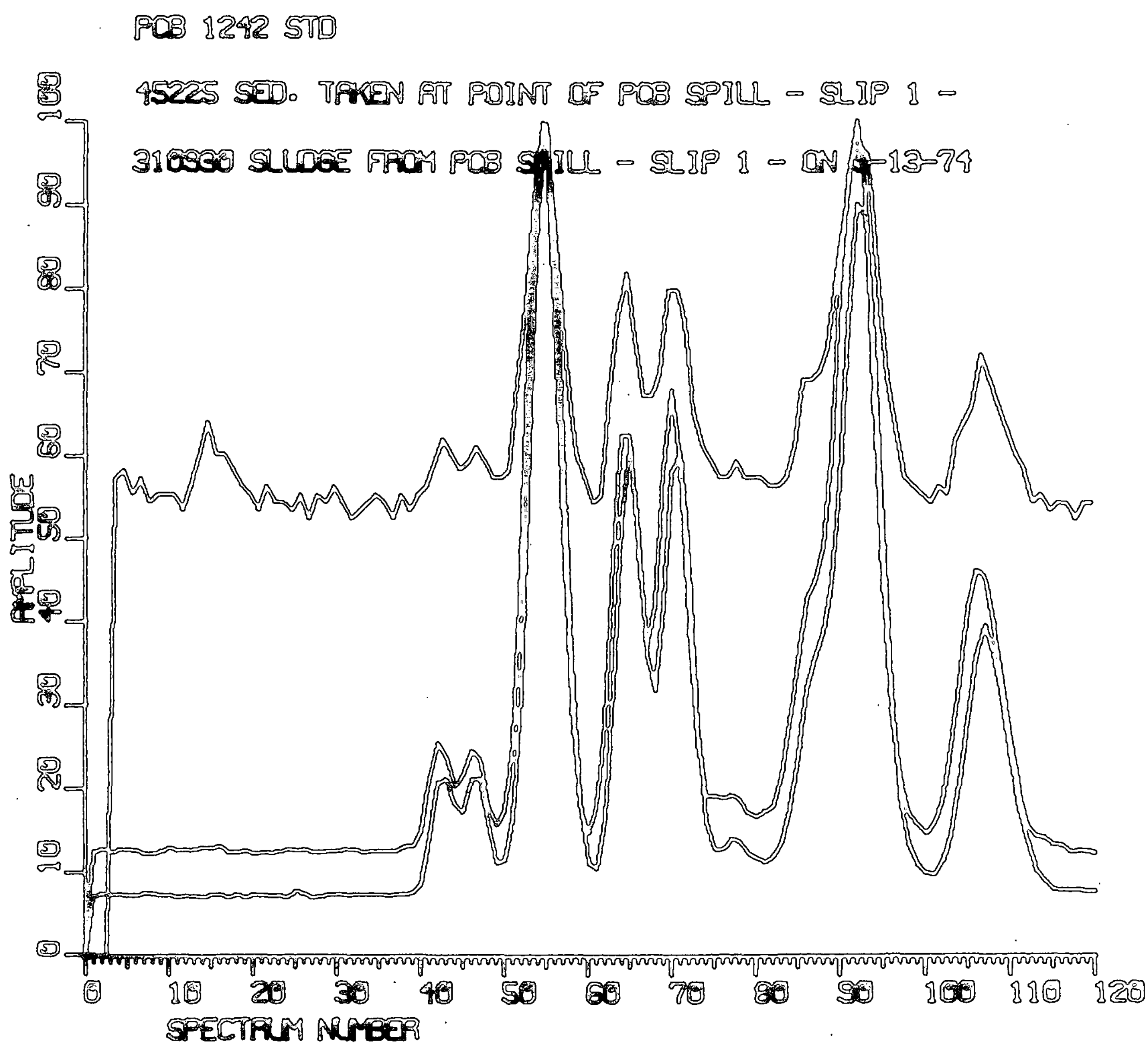


FIGURE B-10

RECONSTRUCTED GAS CHROMATOGRAM
MASS RANGE: 290-300

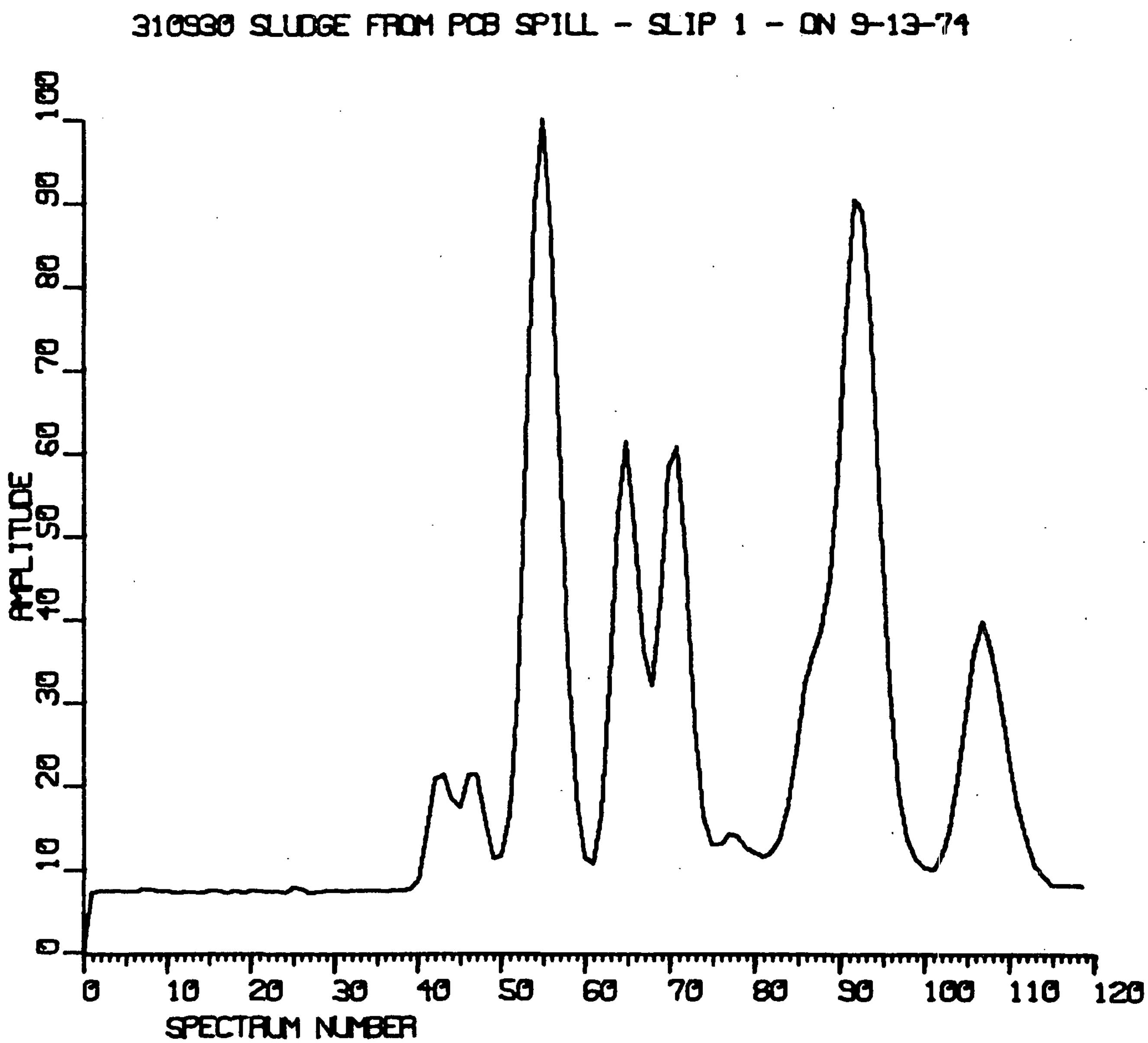


FIGURE B-11

RECONSTRUCTED GAS CHROMATOGRAM
MASS RANGE: 290-300

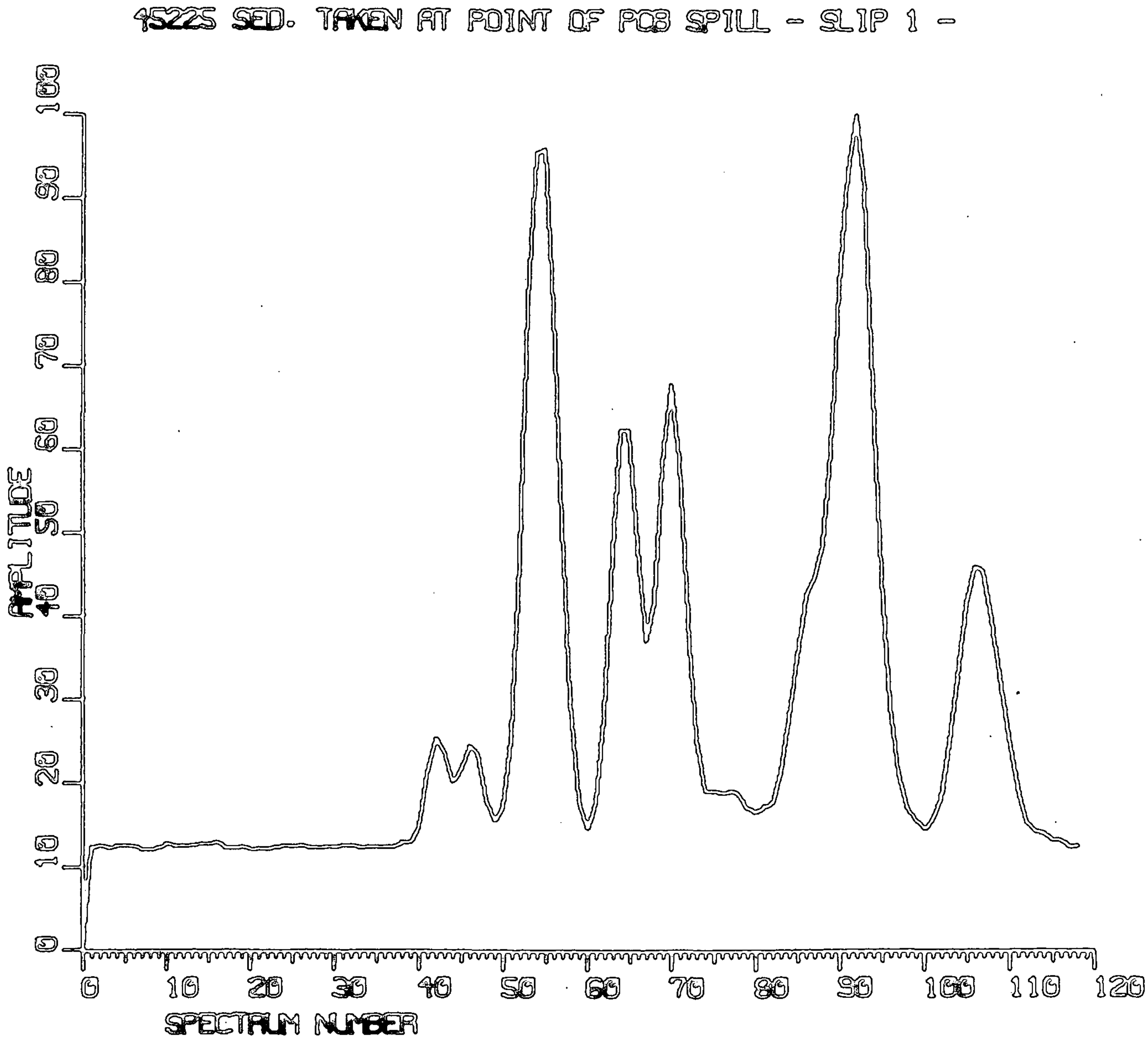


FIGURE B-12

RECONSTRUCTED GAS CHROMATOGRAM
MASS RANGE: 290-300

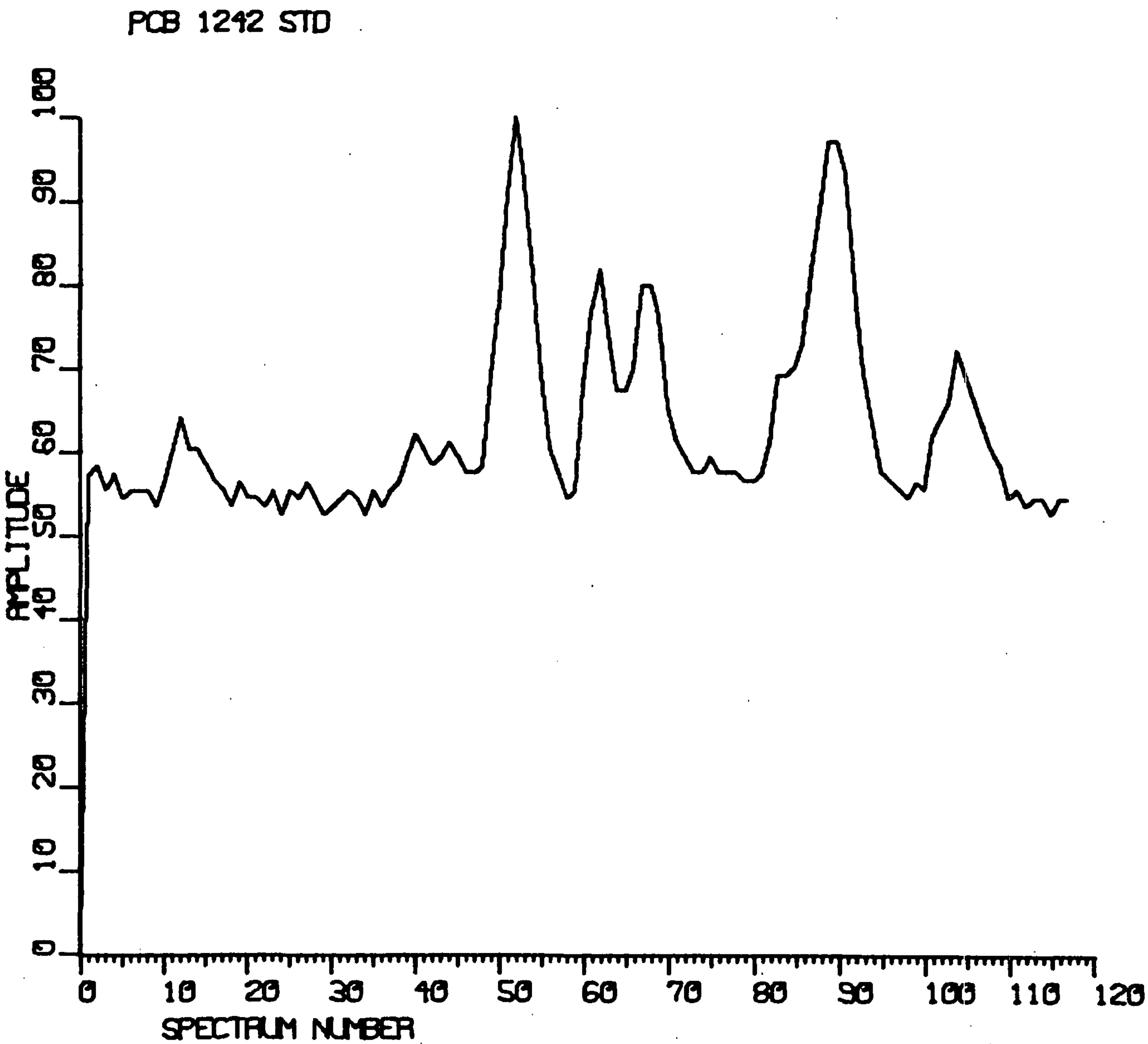


FIGURE B-13

SPECTRUM NUMBER 40 - 39

316333 SLUDGE FROM PCB SPILL - SLIP 1 - ON 9-13-79

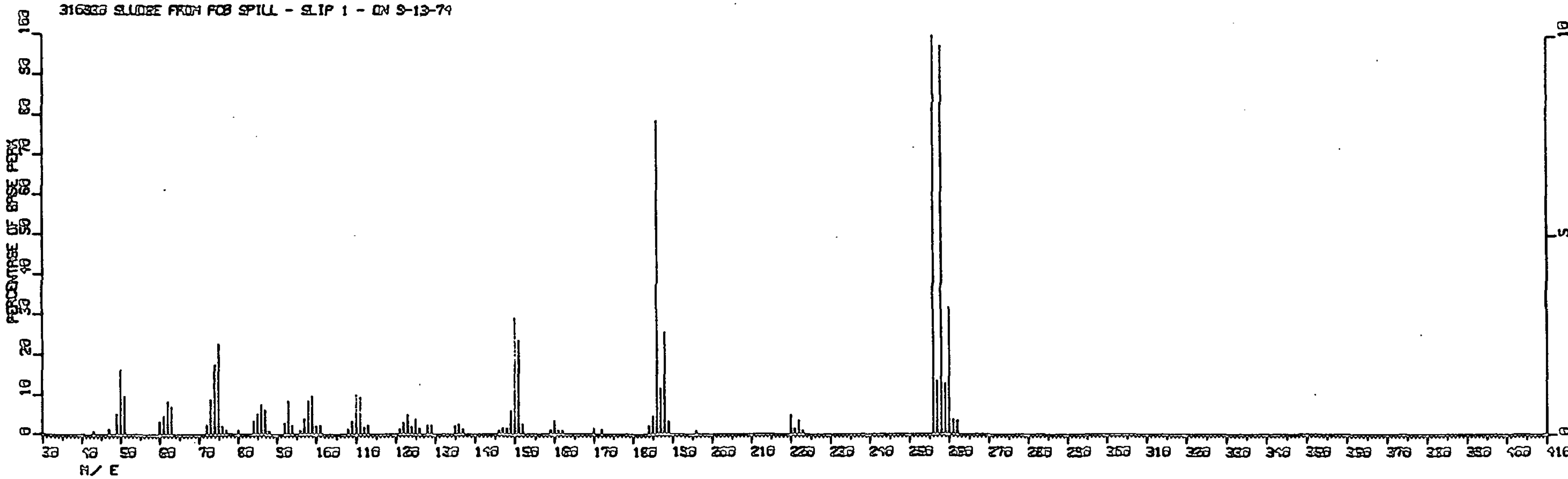


FIGURE B-14

SPECTRUM NUMBER 40 - 34

15225 SED. TAKEN AT POINT OF PCB SPILL - SLIP 1 -

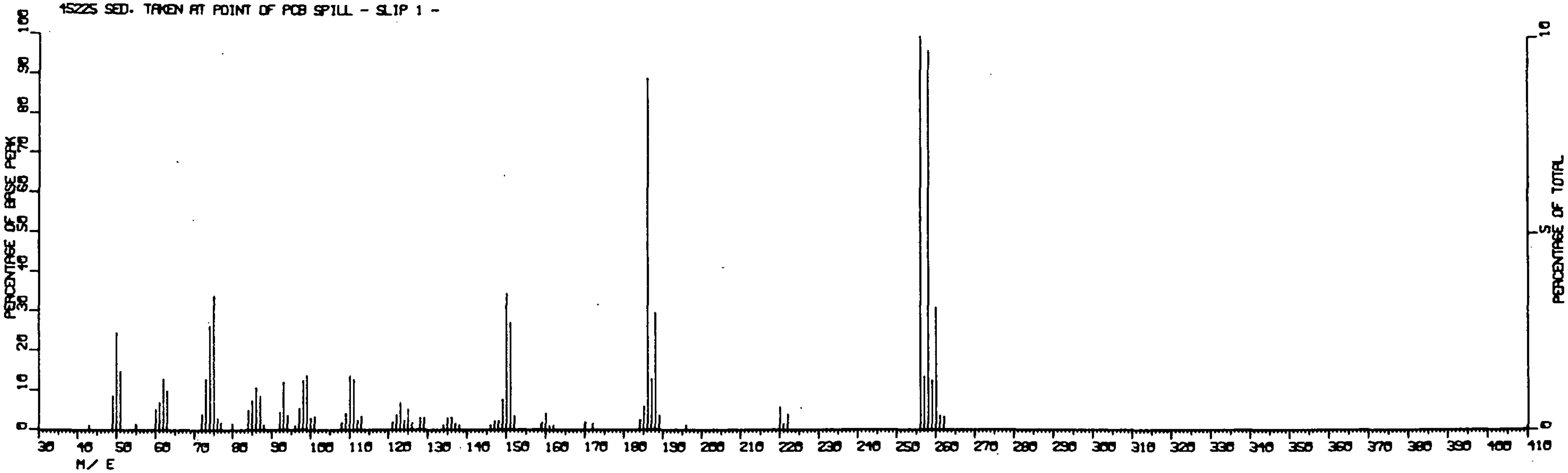
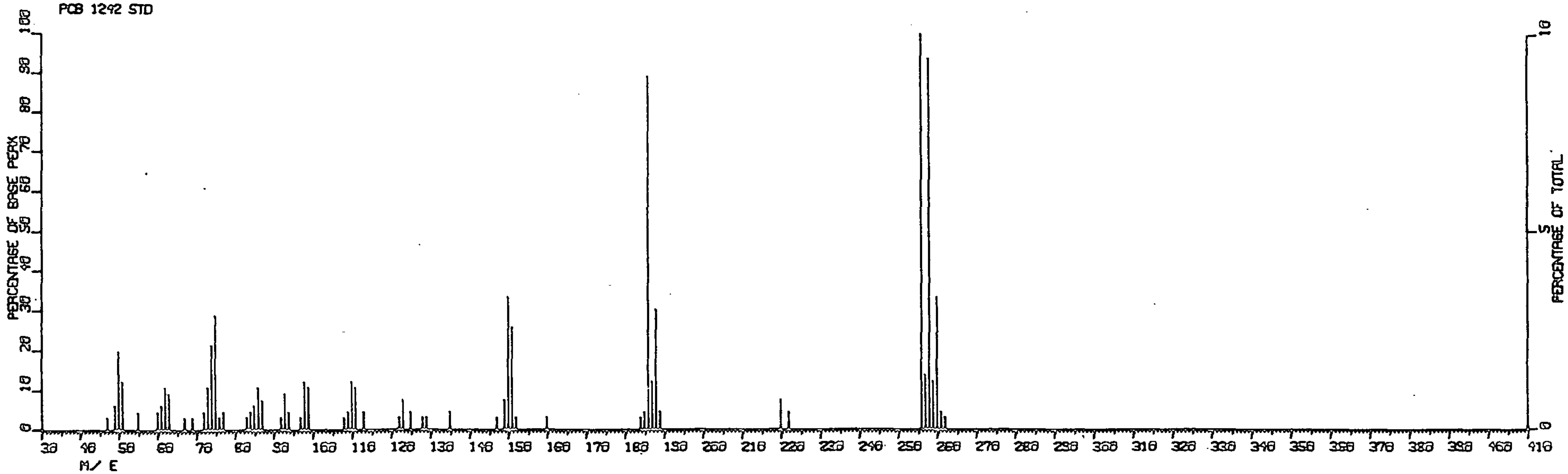


FIGURE B-15

SPECTRUM NUMBER 40 - 34

PCB 1242 STD



Appendix C

TABLE OF CONTENTS

Section I

Results
of
Predredge Analysis
of
Slip 1
Sediments

TABLE C-1. COMPOSITION OF SEDIMENTS IN SLIP 1 BEFORE DREDGING

Parameter		Composite Samples from Designated Areas 1	2	3 & 4	5	6
PCB	ug/g	72	8	2	< 1	1
As	ug/g	8	7	8	5	6
Cd		0.5	1.4	5.0	2.8	0.6
Cr		21	37	20	22	15
Cu		39	42	59	52	32
Fe		25,100	21,800	21,000	24,500	18,300
Pb		44	235	84	67	44
Mn		250	250	220	240	180
Hg		0.1	0.1	0.1	0.1	< 0.1
Zn		110	310	1,000	610	120
P	ug/g	590	530	520	540	510
N-TKN		630	690	460	580	480
$N-NH_3$		14	17	15	23	69
COD	ug/g	28,200	28,400	28,700	20,900	26,200
Grease/Oil		715	737	1,120	700	361
Sulfide		42	42	86	99	53
Solids	%	42.5	44.1	40.7	47.7	46.5
Solids-Volatile	%	8.9	9.3	10.4	7.5	7.1
E_h volts		+0.084	+0.022	-0.059	+0.006	+0.015
Density	g/ml	1.36	1.32	1.36	1.36	1.36

Units expressed on wet weight basis

Table C-2
COMPOSITION OF ELUTRIATE WATER FROM PREDREDGED SEDIMENT SAMPLES FROM SLIP 1

Parameter		Dredge Site Water	Composite Sample from Designated Areas 1	2	3 + 4	5	6
PCB	ug/l	<0.010	158	29	30	13	8
As	ug/l	2.1	16.2	12.2	15.9	6.9	11.7
Cd		8.	4.	8.	4.	4.	4.
Cr		16	45	43	43	47	47
Cu		7.2	6.0	7.2	3.6	18.0	9.0
Fe		1,300	560	300	240	260	540
Mn		80	2,880	1,320	224	1,920	3,360
Hg		0.4	0.1	0.1	0.2	0.6	0.1
Ni		<10	<10	<10	<10	<10	<10
Zn		20.	12.	4.	<2	8.	4.
P-Total (a)	mg/l	-	0.19	0.80	0.81	0.24	0.12
(b)		0.098	0.11	0.39	0.52	0.19	0.07
N-TKN		0.17	4.5	5.8	4.8	3.0	5.0
$N-NH_3$		0.04	3.3	3.8	2.6	2.2	3.0
$N-NO_3 + NO_2$		0.41	1.4	0.20	0.30	0.29	0.31
Grease/Oil	mg/l	<1	1.9	7.6	13	3.0	1.2
TOC		3.	17.	24.	42	15.	15.
pH		-	-	-	-	-	-

(a) Sample centrifuged but not filtered
(b) Sample centrifuged and filtered thru 0.45 μ membrane

Table C-3
COMPOSITION OF INTERSTITIAL WATER FROM PREDREDGED SEDIMENT SAMPLES FROM SLIP 1

Parameter		Dredge Site Water	Composite Sample from Designated Areas 1	2	3 + 4	5	6
PCB	ug/l	< 0.010	1,700	143	147	85	51
As	ug/l	2.1	21.2	32.3	21.5	20.4	26.5
Cd		8.	6.	4.	4.	6.	4.
Cr		16	15	34	43	44	48
Cu		7.2	6.0	7.2	4.8	9.6	9.0
Fe		1,300	4,000	410	200	8,400	40,000
Mn		80	1,640	1,920	220	5,280	9,760
Hg		0.4	0.4	0.1	0.3	1.0	0.1
Ni		<10	<10	<10	<10	<10	<10
Zn		20.	38.	10.	< 2.	74.	10.
P-Total (a)	mg/l		3.32	4.50	2.84	3.94	1.36
(b)		0.098	1.8	1.76	1.36	.26	.20
N-TKN		0.17	12.	17.	16.	12.	12.
$N-NH_3$		0.04	9.0	11.	6.2	5.5	8.2
$N-NO_3 + NO_2$		0.41	0.23	0.22	0.25	0.48	0.57
$N-NO_2$		-	0.16	0.16	0.17	0.25	0.28
Grease/Oil	mg/l	-	-	-	-	-	-
TOC		3.	46.	79.	64.	54.	46.
pH		7.45	6.9	7.8	8.65	7.4	7.2

(a) Sample centrifuged but not filtered
(b) Sample centrifuged and filtered thru .45 μ membrane

Section II

Results
of
Analysis
of
Influent to Pond 1 and
Effluents from Holding Ponds 1 and 2

TABLE C-4. ANALYSIS OF INFLUENT TO POND 1

Date of Sampling
16 March 1976 (076 Julian)

	Influent		Centrifuged Influent			
Parameter	Wet Wt.		Water		Solids Wet wt.	
PCB			37	ug/l	[redacted]	
Na					6.9	mg/g
K					1.8	
Ca					13.8	
Mg					14.5	
As			84	ug/l	11	ug/g
Cd			<2		4.6	
Cr			-		-	
Cu			72		87	
Fe			250		24,770	
Mn			100		270	
Hg			0.2		0.2	
Ni			20		39	
Zn			6		1,030	
P-O			0.39	mg/l	-	
P-Total			0.43		800	mg/Kg
N-TKN			8.2		480	
$N-NH_3$			7.8			
$N-NO_3$			0.29			
$N-NO_2$			0.075			
Alkalinity			367	mg/l		
Chloride			15,800			
COD			-		55,000	mg/Kg
TOC			11			
Grease/Oil	795	mg/Kg	41.5		3,324	mg/Kg
Sulfate			2,000			
Sulfide	71	mg/Kg	<0.02			
Solids-Settleable	300	ml/l	-			
Solids-Total	125,600	mg/l	-		845	mg/Kg
Solids	10.5	%	-		52.6	%

TABLE C-5. ANALYSIS OF INFLUENT TO POND 1

Date of Sampling
19 March 1976 (079 Julian)

Parameter	Influent Wet wt.		Centrifuged Influent Water		Centrifuged Influent Solids Wet wt.	
PCB			4.1	ug/l	[redacted]/g	
Na					6.2	mg/g
K					1.5	
Ca					14.1	
Mg					18.3	
As			117	ug/l	9	ug/g
Cd			<2		3.5	
Cr			-		-	
Cu			48		73	
Fe			240		24,200	
Mn			78		121	
Hg			<0.2		0.5	
Ni			<10		49	
Zn			6		480	
P-O			0.40	mg/l	-	
P-Total			0.49		792	mg/Kg
N-TKN			16		1,230	
$N-NH_3$			16			
$N-NO_3$			0.31			
$N-NO_2$			0.024			
Alkalinity			552	mg/l		
Chloride			16,000			
COD					59,100	mg/Kg
TOC			19			
Grease/Oil	183	mg/Kg	48		4,110	
Sulfate			1,800			
Sulfide	99	mg/Kg	0.08			
Solids-Settleable	300	ml/l				
Solids-Total	64,800	mg/l				
Solids	3.2	%			48.4	%

TABLE C-6. ANALYSIS OF INFLUENT TO POND 1

Date of Sampling
22 March 1976 (0830)
082.3

	Influent		Centrifuged Influent			
Parameter	Wet Wt.		Water		Solids Wet wt.	
PCB			10.6	ug/l	[redacted]	ug/g
Na					5.3	mg/g
K					1.8	
Ca					7.8	
Mg					8.7	
As			19	ug/l	10	ug/g
Cd			<2		2.3	
Cr			-		-	
Cu			46		62	
Fe			250		26,100	
Mn			260		274	
Hg			<0.2		0.3	
Ni			30		29	
Zn			8		365	
P-O			0.45	mg/l		
P-Total			0.44		721	mg/Kg
N-TKN			4.8		333	
$N-NH_3$			3.4			
$N-NO_3$			0.3			
$N-NO_2$			0.04			
Alkalinity			197	mg/l		
Chloride			16,200			
COD					48,400	mg/Kg
TOC			6			
Grease/Oil	147	mg/Kg	2.8		2,780	
Sulfate			2,100			
Sulfide	27	mg/Kg	<0.02			
Solids-Settleable	220	ml/l				
Solids-Total	95,800	mg/l				
Solids	3.8	%			52.9%	

TABLE C-7. ANALYSIS OF INFLUENT TO POND 1

Date of Sampling
22 March 1976 (1400)
082.5

Parameter	Influent Wet wt.		Centrifuged Influent Water		Centrifuged Influent Solids Wet wt.	
PCB			54	ug/l	[redacted]	
Na					6.5	mg/g
K					-	
Ca					5.8	
Mg					7.0	
As			88	ug/l	8	ug/g
Cd			<2		2.6	
Cr			-		-	
Cu			44		63	
Fe			270		22,200	
Mn			208		230	
Hg			<0.2		0.4	
Ni			20		22	
Zn			<2		274	
P-O			3.1	mg/l		
P-Total			3.1		727	mg/Kg
N-TKN			27		463	
$N-NH_3$			14			
$N-NO_3$			0.1			
$N-NO_2$			0.03			
Alkalinity			466	mg/l		
Chloride			16,300			
COD					55,940	mg/Kg
TOC			14			
Grease/Oil	1,497	mg/Kg	12		4,149	
Sulfate			1,950			
Sulfide	45	mg/Kg	0.02			
Solids-Settleable	800	ml/l				
Solids-Total	152,500	mg/l				
Solids	12.4	%			56.8	%

TABLE C-8. ANALYSIS OF INFLUENT TO POND 1

Date of Sampling
23 March 1976 (083 Julian)

	Influent		Centrifuged Influent			
Parameter	Wet wt.		Water		Solids Wet wt.	
PCB			13	ug/l	[redacted]	
Na					5.8	mg/g
K					-	
Ca					6.1	
Mg					6.1	
As			14	ug/l	7.9	ug/g
Cd			<2		2.4	
Cr			-		-	
Cu			52		74	
Fe			360		26,700	
Mn			340		255	
Hg			<0.2		0.3	
Ni			20		23	
Zn			16		319	
P-O			0.31	mg/l		
P-Total			0.34		736	mg/Kg
N-TKN			3.8		413	
$N-NH_3$			3.6			
$N-NO_3$			0.14			
$N-NO_2$			0.03			
Alkalinity			158	mg/l		
Chloride			16,200			
COD					52,246	mg/Kg
TOC			6			
Grease/Oil	288	mg/Kg	2		1,669	mg/Kg
Sulfate			1,930			
Sulfide	28	mg/Kg	<0.02			
Solids-Settleable	140	ml/l				
Solids-Total	54,990	mg/l				
Solids	3.5	%			57.0	%

TABLE C-9. ANALYSIS OF EFFLUENTS FROM POND 1

Parameter		Effluent 4-3 094.5	Centrifuged Effluent 4-3 094.5	Effluent 4-4 095.5	Centrifuged Effluent 4-4 095.5
PCB	ug/l	1.2	0.48	6	0.39
Turbidity	NTU	11	-	21	-
As	ug/l	16	16	8	14
Cd		< 2	< 2	< 2	< 2
Cr		28	26	24	24
Cu		56	52	54	60
Fe		460	200	540	200
Mn		166	162	184	176
Hg		0.2	0.2	0.2	0.2
Zn		16	14	24	16
P-O	mg/l	-	0.30	-	0.30
P-Total		0.35	0.30	0.39	0.31
N-TKN		-	4.2	-	4.1
N-NH_3		-	4.1	-	4.2
N-NO_3		-	0.36	-	0.34
N-NO_2		-	0.024	-	0.023
Alkalinity	mg/l	-	177	-	179
Chloride		-	15,700	-	15,700
TOC		-	6	-	6
Grease/Oil		3	6	7	5
Sulfate		-	2,130	-	2,150
Sulfide		-	-	-	< 0.02
Solids-Settleable	ml/l	< 0.01	-	0.6	-
Solids-NF, %		.01	-	-	-
Solids, Total	mg/l	29,800	-	29,570	-

TABLE C-10. ANALYSIS OF EFFLUENTS FROM POND 1

Parameter		Effluent 4-6 097.5	Centrifuged Effluent 4-6 097.5
PCB (ppb)	ug/l	16	1.9
Turbidity	NTU	36	-
As	ug/l	5.5	6.0
Cd		5	<3
Cr		56	25
Cu		120	58
Fe		4,900	175
Mn		660	430
Hg		1.1	0.3
Zn		273	48
P-O	mg/l	-	0.27
P-Total		1.1	0.28
N-TKN		-	7.2
$N-NH_3$		-	7.1
$N-NO_3$		-	0.33
$N-NO_2$		-	0.022
Alkalinity	mg/l	-	193
Chloride		-	15,500
TOC		-	12
Grease/Oil		256	4
Sulfate		-	1,900
Sulfide		-	-
Solids-Settleable	ml/l	1.2	-
Solids-NF, %		0.03	-
Solids, Total	mg/l	33,948	-

TABLE C-11. ANALYSIS OF EFFLUENTS FROM POND 2

Parameter		Effluent 3-16 076.5	Centrifuged Effluent 3-16 076.5	Effluent 3-19 079.5	Centrifuged Effluent 3-19 079.5
PCB	ug/l	<0.08	< 0.08	1.1	0.25
Turbidity	NTU	48	-	26	-
As	ug/l	9	3	5	3
Cd		8	4	6	4
Cr		-	-	-	-
Cu		36	34	48	36
Fe		4,800	740	1,800	200
Mn		1,520	1,400	1,320	1,280
Hg		0.1	0.1	< 0.2	< 0.2
Ni		10	10	<10	<10
Zn		252	228	480	216
P-O	mg/l	-	< 0.01	-	0.02
P-Total		0.19	0.01	0.15	0.03
N-TKN		-	7.5	-	7.8
$N-NH_3$		-	7.2	-	7.4
$N-NO_3$		-	0.36	-	0.34
$N-NO_2$		-	0.02	-	0.02
Alkalinity	mg/l	-	206	-	209
Chloride		-	8,800	-	10,600
TOC		-	16	-	14
Grease/Oil		5.4	4.1	4.4	3.6
Sulfate		-	1,200	-	1,500
Sulfide		<0.02	<0.02	< 0.02	< 0.02
Solids-Settleable	ml/l	0.4	-	0.2	-
Solids-NF, %		<0.01	-	<0.01	-
Solids-Total	mg/l	20,330	-	23,090	-

TABLE C-12. ANALYSIS OF EFFLUENTS FROM POND 2

Parameter		Effluent 3-22 082.4	Centrifuged Effluent 3-22 082.4	Effluent 3-22 082.7	Centrifuged Effluent 3-22 082.7
PCB	ug/l	< 0.05	< 0.05	< 0.1	< 0.08
Turbidity	NTU	17	-	18	-
As	ug/l	12	21	13	11
Cd		8	4	8	< 2
Cr		-	-	-	-
Cu		36	32	42	28
Fe		1,560	140	1,300	180
Mn		1,120	1,060	900	840
Hg		< 0.2	< 0.2	< 0.2	< 0.2
Ni		30	30	20	20
Zn		400	148	224	100
P-O	mg/l	-	0.06	-	0.1
P-Total		0.17	0.06	0.21	0.11
N-TKN		-	8.2	-	8.2
$N\text{-}NH_3$		-	7.6	-	7.7
$N\text{-}NO_3$		-	0.32	-	0.34
$N\text{-}NO_2$		-	0.035	-	0.02
Alkalinity	mg/l	-	220	-	237
Chloride		-	11,800	-	12,400
TOC		-	12	-	11
Grease/Oil		3.9	3.5	3.6	4.0
Sulfate		-	1,500	-	1,700
Sulfide		0.02	< 0.02	< 0.02	< 0.02
Solids-Settleable	ml/l	< 0.1	-	< 0.1	-
Solids-NF, %		< 0.01	-	< 0.01	-
Solids-Total	mg/l	22,850	-	25,720	-

TABLE C-13. ANALYSIS OF EFFLUENTS FROM POND 2

Parameter		Effluent 3-23 083.4	Centrifuged Effluent 3-23 083.4	Effluent 4-1 092.5	Centrifuged Effluent 4-1 092.5
PCB	ug/l	<0.6	< 1.2	2.8	0.19
Turbidity	NTU	27	-	54	-
As	ug/l	19	16	4	2
Cd		4	< 2	2	< 2
Cr		-	-	24	24
Cu		48	48	60	52
Fe		1,140	280	3,600	200
Mn		840	750	740	760
Hg		< 0.2	< 0.2	0.2	< 0.2
Ni		20	20	-	-
Zn		174	52	152	70
P-O	mg/l	-	0.15	-	0.03
P-Total		0.25	0.15	0.21	0.04
N-TKN		8.2	8.0	-	6.5
$N-NH_3$			7.7	-	6.8
$N-NO_3$			0.35	-	0.44
$N-NO_2$			0.019	-	0.023
Alkalinity	mg/l	-	249	-	188
Chloride		-	13,100	-	-
TOC		-	11	-	9
Grease/Oil		2.6	3.2	-	-
Sulfate		-	1,650	-	1,930
Sulfide		< 0.02	< 0.02	-	-
Solids-Settle-able	ml/l	0.1	-	1.0	-
Solids-NF, %		0.01	-	0.01	-
Solids-Total	mg/l	25,990	-	27,680	-

TABLE C-14. ANALYSIS OF EFFLUENTS FROM POND 2

Parameter		Effluent 4-3 094.5	Centrifuged Effluent 4-3 094.5	Effluent 4-4 095.5	Centrifuged Effluent 4-4 095.5
PCB	ug/l	0.52	0.29	0.45	0.22
Turbidity	NTU	96	-	68	-
As	ug/l	6	0.5	13	0.5
Cd		< 2	< 2	< 2	< 2
Cr		28	20	29	24
Cu		70	46	65	53
Fe		14,000	180	8,400	170
Mn		1,120	104	640	630
Hg		0.2	0.2	0.3	0.2
Zn		-	-	214	55
P-O	mg/l	-	<0.01	-	0.02
P-Total		0.43	0.01	0.41	0.03
N-TKN		-	6.5	-	5.2
$N-NH_3$		-	5.4	-	5.1
$N-NO_3$		-	0.29	-	0.31
$N-NO_2$		-	0.02	-	0.023
Alkalinity	mg/l	-	154	-	172
Chloride		-	12,700	-	14,300
TOC		-	7	-	7
Grease/Oil		-	-	-	-
Sulfate		-	1,680	-	1,830
Sulfide		-	< 0.02	-	< 0.02
Solids-Settleable	ml/l	1.8	-	1.4	-
Solids-NF, %		0.01	-	0.01	-
Solids, Total	mg/l	24,500	-	27,560	-

TABLE C-15. ANALYSIS OF EFFLUENT FROM POND 2

Parameter		Effluent 4-5 096.5	Centrifuged Effluent 4-5 096.5	Effluent 4-6 097.5	Centrifuged Effluent 4-6 097.5
PCB	ug/l	-	-	0.80	0.47
Turbidity	NTU	36	-	18	-
As	ug/l	8.	1.	3.	0.5
Cd		<2	<2	<4	3
Cr		25	24	36	33
Cu		65	42	58	50
Fe		4,000	140	1,890	200
Mn		730	600	680	640
Hg		0.2	0.3	0.4	0.3
Zn		134	44	105	60
P-O	mg/l	-	0.03	-	0.05
P-Total		0.26	0.04	0.21	0.06
N-TKN		5.2	5.8	5.5	5.5
$N-NH_3$		-	5.3	-	5.4
$N-NO_3$		-	0.30	-	0.25
$N-NO_2$		0.1	0.023	-	0.028
Alkalinity	mg/l	-	175	-	184
Chloride		-	14,400	-	14,600
TOC		-	6	-	9
Grease/Oil		-	-	122	13
Sulfate		-	2,000	-	1,850
Sulfide		-	< 0.02	-	-
Solids-Settle-able	ml/l	0.1	-	0.2	-
Solids-NF, %		-	-	0.01	-
Solids, Total	mg/l	28,060	-	30,410	-

Section III

Post-Dredge
Analysis
of Sediments
at Slip 1

TABLE C-16. COMPOSITION OF POST DREDGE SEDIMENT SAMPLES

Parameter		Composite Sample from Designated Areas 1	2	3	4	5	6
PCB	ug/g	50	10	3	2	2	3
As	ug/gm	8	7.3	6.9	8.6	9.3	6
Cd		1.0	3.0	3.2	9.9	3.0	0.8
Cr		27	-	18	20	-	23
Cu		52	56	48	82	58	44
Fe		21,300	16,350	12,700	21,200	19,770	21,200
Pb		61	109	84	274	107	60
Mn		186	173	156	215	217	196
Hg	ug/g	0.2	0.5	0.3	0.2	0.2	0.2
Zn		1,390	3,270	458	2,550	650	126
P-Total	ug/g	580	550	460	540	550	530
N-TKN		-	820	630	600	660	810
$N-NH_3$		25	320	20	15	85	30
Grease/Oil	mg/Kg	2,445	4,060	2,255	2,035	1,525	1,720
pH		7.5	9.1	9.4	8.9	7.9	7.3
Sulfide	ug/g	170	470	310	190	170	180
% Solids		45.4	39.5	25.9	37.9	48	46.1
% Volatile Solids		8.2	10.8	14.7	10.9	8.5	8.9
COD		40,100	45,100	33,200	37,500	36,000	39,500
Eh volts		0.026	-0.008	-0.166	-0.088	0.007	0.033

TABLE C-17
COMPOSITION OF INTERSTITIAL WATER FROM SEDIMENT SAMPLES AFTER DREDGING

Parameter		Composite Sample from Designated Areas 1	2	3	4	5	6
PCB	ug/l	260	590	220	75	80	140
As	ug/l	28	104	180	26	48	22
Cd		<4	4	<4	<4	<4	<4
Cr		32	-	24	28	-	32
Cu		56	50	44	52	56	56
Fe		10,200	840	680	760	1,020	1,860
Mn		2,040	162	54	156	1,520	2,280
Hg	ug/l	0.6	0.5	0.6	0.6	0.3	0.8
Zn		4	8	≤4	<4	<4	4
P-Total	(mg/l)						
Filter		3.0	4.7	0.75	2.1	3.5	0.38
Unfiltered		0.96	4.9	0.77	2.0	4.8	0.81
Filtered/He		4.3	3.7	0.80	2.0	3.6	0.93
N-TKN		18	79	76	39	40	35
$N-NH_3$		12	32	34	12	12	16
$N-NO_3$		0.10	0.07	0.10	0.12	0.25	0.27
$N-NO_2$		0.200	0.014	0.040	0.120	0.150	0.310
TOC	(mg/l)	35	58	29	96	72	50
Grease/Oil		74	157	305	278	87	31
pH		7.5	8.6	9.1	8.2	7.7	7.9
Conductivity (micromhos/cm)		39,300	39,050	33,300	37,900	35,800	34,300

Section IV

Water
Analysis
at
Dredge
and
Background
Sites

TABLE C-18. WATER ANALYSIS AT DREDGE AND BACKGROUND SITES

Predredge - Cruise 1
25 Feb. 1976 - Julian date 058

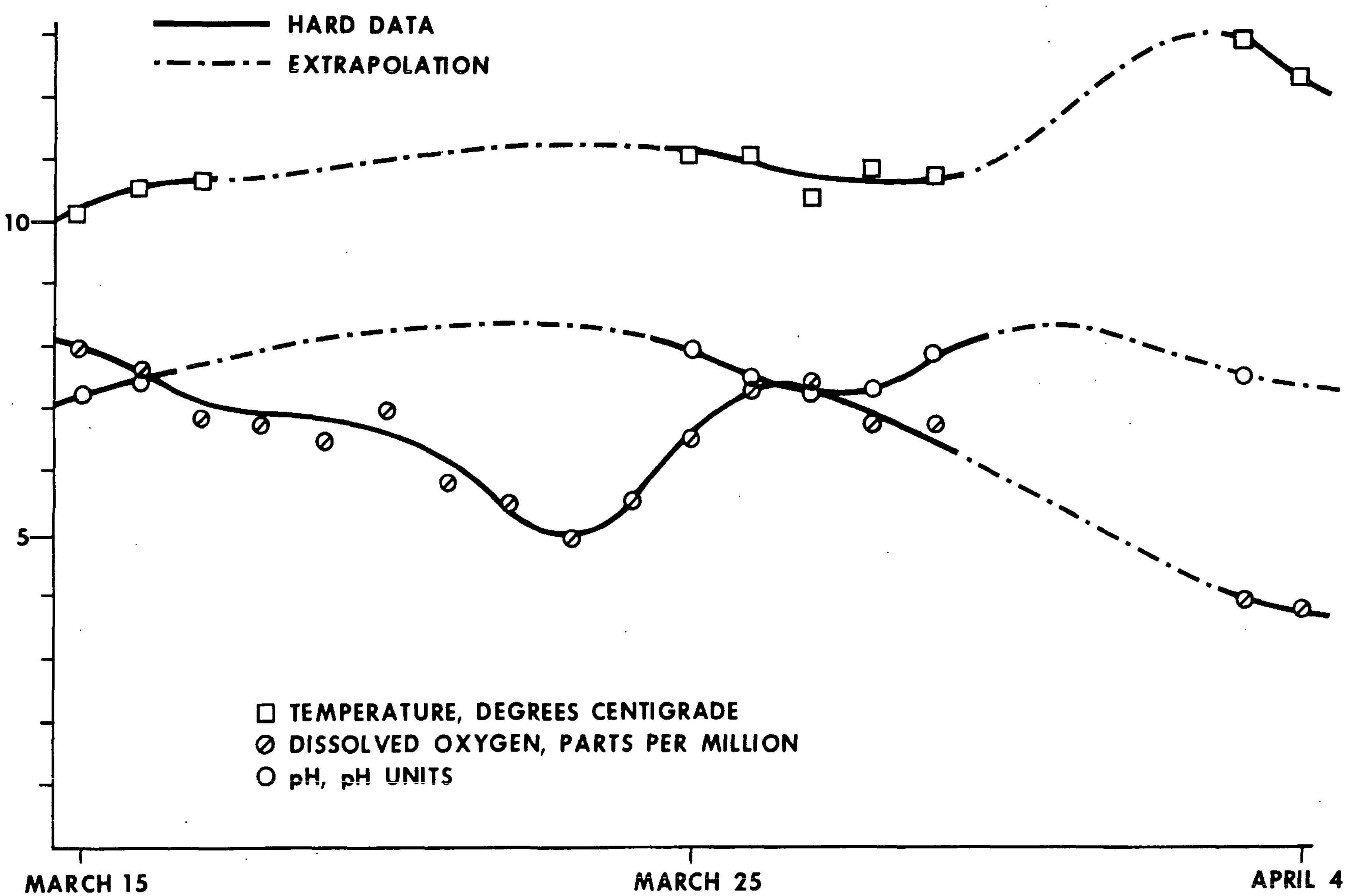
		Dredge Site		Background		
Parameter		Fresh Water	Salt Water	Fresh Water RM-2.99	Salt Water	Fresh Water RM-5.47
PCB	ug/l	0.020	0.014	0.022	0.013	0.020
Turbidity	NTU	3.6	1.1	4.4	0.8	3.3
As	ug/l	<1	12	3	9	<1
Cd		<2	<2	<2	4	<2
Cr		12.	48	7	41	2
Cu		5.	4.	2.	4.	7.
Fe		620	300	700	300	680
Mn		52	48	48	48	40
Hg		0.1	<0.1	0.1	0.3	0.2
Ni		<10	<10	<10	<10	<10
Zn		11	<3	20	2	14
P-Ortho	mg/l	0.08	0.08	0.08	0.08	0.08
P-Total		0.15	0.08	0.15	0.08	0.15
N-TKN		0.42	0.13	0.51	0.84	0.53
$N-NH_3$		0.30	0.03	0.41	0.04	0.42
$N-NO_3$		0.49	0.41	0.50	0.41	0.50
$N-NO_2$		0.009	0.009	0.008	0.009	0.007
Grease/Oil	mg/l	0.4	0.1	0.3	0.2	-
TOC		5.	4.	4.	2.	5.
Sulfide		<0.02	<0.02	<0.02	<0.02	<0.02

TABLE C-19. WATER ANALYSIS AT DREDGE AND BACKGROUND SITES

Dredge - Cruise 2
6 Mar. 1976 - Julian Date 066

Parameter		Dredge Site Fresh Water	Dredge Site Salt Water	Background Fresh Water RM-2.99	Background Salt Water RM-5.47
PCB	ug/l	0.027	0.018	0.022	0.014
Turbidity	NTU	2.4	1.3	2.7	1.4
As	ug/l	1.	1.	1.	1.
Cd		<2	<2	<2	<2
Cr		10	38	7	37
Cu		4.	6.	2.	5.
Fe		460	310	520	480
Mn		64	56	72	72
Hg		0.1	0.1	0.1	0.3
Ni		<10	<10	<10	<10
Zn		12	5	10	<2
P-Ortho	mg/l	0.04	0.05	0.04	0.04
P-Total		0.11	0.09	0.11	0.09
N-TKN		0.45	0.04	0.49	0.04
$N-NH_3$		0.44	0.04	0.48	0.04
$N-NO_3$		0.51	0.39	0.51	0.36
$N-NO_2$		0.008	0.010	0.008	0.011
Grease/Oil	mg/l	0.2	<0.1	0.2	0.1
TOC		3.	2.	3.	3.
Sulfide		<0.02	<0.02	<0.02	<0.02

FIGURE F-2



TEMPERATURE, DISSOLVED OXYGEN AND pH - EFFLUENT POND 2

TABLE C-22. WATER ANALYSIS AT DREDGE AND BACKGROUND SITES

Dredge - Cruise 5
22 March 1976 - Julian Date 082

Parameter		Dredge Site Fresh Water	Dredge Site Salt Water	Background Fresh Water RM-2.99	Background Salt Water RM-5.47
PCB	ug/l	0.021	0.021	0.014	0.013
Turbidity	NTU	1.8	1.1	1.3	0.6
As	ug/l	2	2	2	2
Cd		<2	<2	<2	<2
Cr		9	31	8	36
Cu		11	40	12	44
Fe		430	380	440	320
Mn		53	65	62	64
Hg		0.4	0.2	0.2	0.2
Ni		<10	<10	<10	<10
Zn		9	<2	22	6
P-Ortho	mg/l	0.09	0.06	0.08	0.06
P-Total		0.15	0.12	0.17	0.10
N-TKN		0.34	0.22	0.43	0.07
$N-NH_3$		0.26	0.12	0.37	0.03
$N-NO_3$		0.40	0.39	0.39	0.39
$N-NO_2$		0.008	0.008	0.009	0.006
Grease/Oil	mg/l	0.4	0.2	0.1	0.1
TOC		4	3	4	3

TABLE C-23. WATER ANALYSIS AT DREDGE AND BACKGROUND SITES

Dredge - Cruise 6
23 March 1976 - Julian Date 083

Parameter		Dredge Site Fresh Water	Dredge Site Salt Water	Background Fresh Water RM-2.99	Background Salt Water RM-5.47
PCB	ug/l	0.140	0.460	0.016	0.010
Turbidity		1.6	3.2	2.0	0.7
As	ug/l	3	5	3	3
Cd		<2	< 2	< 2	< 2
Cr		9	31	8	34
Cu		16	36	12	36
Fe		460	490	540	400
Mn		54	56	54	54
Hg		< 0.2	0.2	< 0.2	< 0.2
Ni		<10	<10	<10	< 10
Zn		12	7	26	6
P-Ortho	mg/l	0.09	0.06	0.08	0.06
P-Total		0.16	0.10	0.15	0.09
N-TKN		0.44	0.09	0.40	0.06
$N-NH_3$		0.35	0.04	0.34	0.04
$N-NO_3$		0.40	0.39	0.40	0.39
$N-NO_2$		0.010	0.007	0.010	0.007
Grease/Oil	mg/l	0.3	0.3	0.1	< 0.1
TOC		4	4	5	3

TABLE C-24. WATER ANALYSIS AT DREDGE AND BACKGROUND SITES

Post Dredge - Cruise 7
20 April 1976 - Julian Date 111

Parameter		Dredge Site Fresh Water	Dredge Site Salt Water	Background Fresh Water RM-2.99	Background Salt Water RM-5.47
PCB	ug/l	0.009	0.006	0.009	0.007
Turbidity	NTU	2.3	1.8	2.8	2.1
As	ug/l	< 1	1	< 1	2
Cd		< 2	< 2	< 2	< 2
Cr		6	28	6	28
Cu		17	54	14	60
Fe		330	310	400	360
Mn		47	36	52	36
Hg		0.4	0.6	0.6	1.0
Ni		-	35	30	-
Zn		19	4	16	6
P-Ortho	mg/l	0.09	0.06	0.09	0.06
P-Total		0.15	0.08	0.16	0.09
N-TKN		0.38	0.10	0.48	0.10
$N-NH_3$		0.36	0.04	0.38	0.04
$N-NO_3$		0.33	0.34	0.33	0.34
$N-NO_2$		0.008	0.010	0.007	-
Grease/Oil	mg/l	0.3	0.2	0.2	< 0.1
TOC		4	3	4	3

Section V

Exchange Analysis and Exchange Capacity of Sediments and Solids

TABLE C-25. EXCHANGE CAPACITY OF SEDIMENTS AND SOLIDS

Parameter	Sediment from Slip 1 Site	Solids from Influent	Solids from Pond #2 Effluent
Cation Exchange Capacity			
Wet wt., ug/g	10540	8410	9290
Dry wt., ug/g	16310	16090	20230
Meq/100 g (dry wt.)	70.9	70.0	88.0
Exchangeable Ammonium			
Wet, mg NH_4-N/Kg	30.4	5	56
Dry, mg NH_4-N/Kg	47	10	122

TABLE C-26. SEDIMENT-EXCHANGE ANALYSIS
SEDIMENT FROM SLIP 1 SITE

Parameter Concn. ug/g		Sediment	NH_4OAc Extract of Sediment	HOAc Extract of NH_4OAc Extracted Sediment	$HONH_2$ Extract of HOAc Extracted Sediment	H_2O_2 + HNO_3 Digest NH_4OAc + HNO_3 Extract of $HONH_2$ Sed.	H_2O_2+HNO_3 Digest HNO_3 Extract of $HONH_2$ Sed.	HF+HNO_3 Digest of NHOAc + HNO_3	HF + HNO_3 Digest of HNO_3 Extract
K	wet	2311	1004	119	52	152	159	4934	5780
	dry	3580	1550	205	94	275	287	8900	10400
Ca	wet	13300	1180	3970	960	3910	3710	8810	10960
	dry	20600	1800	6800	1700	7100	6800	16000	20000
Na	wet	10390	4067	222	27	283	293	11010	9300
	dry	17880	6300	380	48	510	530	20000	17000
Mg	wet	10300	2000	500	100	4200	2800	6200	6200
	dry	15960	2500	780	130	7600	5100	11000	11000
Fe	wet	24000	8.6	3500	840	5100	5400	18900	10000
	dry	37150	13.4	6000	1500	9200	9800	34000	18000
Ni	wet	22	0.5	2.4	0.8	8.7	9.9	31	32
	dry	34	0.8	4.1	1.5	16	18	56	58
Mn	wet	303	18	50	11	71	69	187	219
	dry	470	28	86	20	128	125	338	396
Cu	wet	51	0.2	0.2	0.1	28	40	26	27
	dry	78	0.3	0.3	0.2	51	72	48	49
Cr	wet	-	0.06	0.8	0.5	9.8	9.6	23	24
	dry	-	0.10	1.4	1.0	18	17	42	43
Cd	wet	≤ 0.9	≤ 0.01	≤ 0.04	≤ 0.04	0.4	0.7	≤ 0.2	≤ 0.17
	dry	≤ 1.4	≤ 0.02	≤ 0.07	≤ 0.07	0.78	1.32	≤ 0.40	≤ 0.30
Zn	wet	147	0.4	13	8.3	48	51	55	68
	dry	227	0.7	23	15	88	106	99	123
As	wet	7.3	0.10	≤ 0.08	≤ 0.08	0.43	2.5	3.96	2.66
	dry	11.3	0.15	≤ 0.14	≤ 0.14	0.78	4.5	7.1	4.8
Hg	wet	0.19	-	-	-	-	-	-	-
	dry	0.29							
Pb	wet	67	0.4	1.0	1.3	23	30	33	37
	dry	103	0.7	1.7	2.3	42	55	60	67

TABLE C-27. SEDIMENT-EXCHANGE ANALYSIS
SOLIDS FROM INFLUENT

Parameter Concn. ug/g		Sediment	NH_4OAc Extract of Sediment	HOAc Extract of NH_4OAc Extracted Sediment	$HONH_2$ Extract of HOAc Extracted Sediment	$H_2O_2 + HNO_3$ Digest $NH_4OAc + HNO_3$ Extract of $HONH_2$ Sed.	$H_2O_2 + HNO_3$ Digest HNO_3 Extract of $HONH_2$ Sed.	HF + NHO_3 Digest of NH_4OAc + HNO_3	HF + HNO_3 Digest of HNO_3 Extract
K	wet	1874	819	88	45	187	175	4658	5897
	dry	3580	1570	157	81	337	316	8400	10600
Ca	wet	9660	1440	2870	800	1530	1550	8900	10900
	dry	18470	2800	5200	1500	2800	2800	16000	20000
Na	wet	12000	4720	182	33	450	406	11640	14740
	dry	21390	9000	320	60	810	730	21000	27000
Mg	wet	9900	1900	700	200	3200	3100	4900	6400
	dry	18840	3600	1200	360	5800	5500	8900	12000
Fe	wet	25100	253	4540	1300	6500	6300	12500	14700
	dry	48030	483	8100	2400	12000	11000	23000	27000
Ni	wet	29	0.5	4.3	2.5	17	12	26	32
	dry	55	1.2	7.7	4.4	32	23	46	58
Mn	wet	209	6	39	10	77	75	130	167
	dry	400	12	70	18	138	135	235	301
Cu	wet	78	0.1	0.2	0.3	53	56	14	13
	dry	150	0.2	0.4	0.5	96	102	26	23
Cr	wet	-	< 0.02	1.8	2.4	28	22	24	26
	dry	-	< 0.05	3.2	4.4	51	40	43	47
Cd	wet	2.9	< 0.01	< 0.05	< 0.07	1.7	1.9	< 0.3	< 0.3
	dry	5.5	< 0.02	< 0.09	< 0.13	3.01	3.38	< 0.6	< 0.6
Zn	wet	319	0.3	7.7	16	132	127	72	96
	dry	609	0.5	14	29	238	228	130	174
As	wet	7.9	0.07	< 0.10	< 0.14	< 0.33	< 0.31	6.9	5.8
	dry	15.1	0.13	< 0.18	< 0.25	< 0.60	< 0.56	12	10
Hg	wet	0.35	-	-	-	-	-	-	-
	dry	0.68							
Pb	wet	109	0.5	1.0	1.1	82	94	32	32
	dry	208	0.9	1.7	1.9	149	169	59	58

TABLE C-28. SEDIMENT-EXCHANGE ANALYSIS
SOLIDS FROM POND 2 EFFLUENT

Parameter Conc. ug/g		Sediment	NH_4OAc Extract of Sediment	HOAc Extract of NH_4OAc Extracted Sediment	$HONH_2$ Extract of HOAc Extracted Sediment	H_2O_2 + HNO_3 Digest NH_4OAc + HNO_3 Extract of $HONH_2$ Sed.	H_2O_2 + HNO_3 Digest HNO_3 Extract of $HONH_2$ Sed.	HF + HNO_3 Digest of NH_4OAc + HNO_3 Extn.	HF + HNO_3 Digest of HNO_3 Extn.
K	wet	1308	396	53	17	98	128	7200	6609
	dry	2850	862	96	31	176	232	13000	12000
Ca	wet	7580	1220	1510	310	1410	1690	11500	14160
	dry	16520	2700	2700	560	2500	3000	21000	26000
Na	wet	13270	3474	165	14	432	439	15500	11160
	dry	25470	7600	300	25	780	790	28000	20000
Mg	wet	8900	1500	1100	100	1200	1400	8300	7900
	dry	19400	3300	2000	260	2200	2400	15000	14000
Fe	wet	37400	1.5	3700	2200	8400	11106	22500	23200
	dry	81600	3.3	6800	4000	15000	20000	41000	42000
Ni	wet	35	2.8	8.5	2.3	8.0	8.4	46	49
	dry	77	6.0	15	4.1	14	15	83	89
Mn	wet	203	5	50	74	30	34	235	253
	dry	440	11	91	133	54	61	424	457
Cu	wet	79	0.3	14	11	30	37	23	21
	dry	171	0.6	26	20	54	67	42	37
Cr	wet	-	0.1	1.4	0.6	45	49	53	64
	dry	-	0.2	2.5	1.0	81	88	95	116
Cd	wet	6.2	0.02	3.1	1.2	0.8	1.2	$\leq$ 0.3	$\leq$ 0.2
	dry	13.4	0.05	5.5	2.1	1.4	2.1	$\leq$ 0.5	$\leq$ 0.4
Zn	wet	500	4.0	324	58	71	85	60	64
	dry	1090	8.7	585	105	129	152	108	116
As	wet	19	4.0	$\leq$0.08	$\leq$0.08	0.38	16	19	12
	dry	41	7.1	$\leq$0.14	$\leq$0.14	0.69	28	33	21
Hg	wet	0.47	-	-	-	-	-	-	-
	dry	1.02							
Pb	wet	164	0.35	9.5	14	46	68	83	86
	dry	356	0.77	17	25	83	122	149	155

TABLE C-29

LOSS OF METALS FROM A DE-IONIZED WATER RINSE OF SEDIMENTS AFTER AMMONIUM ACETATE AND ACID EXTRACTIONS

Parameter Conc. ug/gm		Sediment from Slip 1 After NH_4OAc Extraction	Sediment from Slip 1 After HOAc Extn.	Solids from Influent After NH_4OAc Extn.	Solids from Influent After HOAc Extn.	Solids from Effluent After NH_4OAc Extn.	Solids from Effluent After HOAc Extraction
K	wet	0.5	6.9	0.4	7.4	47	3.6
	dry	0.7	12	0.7	13	103	6.5
Ca	wet	75	103	82	96	74	65
	dry	117	178	157	170	162	117
Na	wet	502	14	570	15	389	12
	dry	780	24	1080	27	850	21
Mg	wet	70	20	70	39	90	50
	dry	103	31	139	55	200	82
Fe	wet	0.4	130	0.4	20	0.1	10
	dry	0.6	219	0.7	34	0.3	18
Ni	wet	<0.06	<0.2	<0.06	<0.2	<0.06	<0.2
	dry	<0.1	<0.3	<0.01	<0.3	<0.1	<0.3
Mn	wet	0.63	1.5	0.30	1.5	0.3	2.1
	dry	0.97	2.53	0.48	2.73	0.67	3.77
Cu	wet	0.05	0.08	0.40	0.14	0.07	0.90
	dry	0.08	0.14	0.69	0.26	0.15	1.63
Cr	wet	<0.01	<0.03	<0.01	0.09	<0.01	0.07
	dry	<0.02	<0.07	<0.02	0.07	<0.02	0.13
Cd	wet	<0.01	<0.04	<0.01	<0.05	<0.01	<0.04
	dry	<0.02	<0.08	<0.02	<0.10	<0.02	<0.08
Zn	wet	0.29	0.99	0.10	0.86	0.28	13.67
	dry	0.45	1.71	0.18	1.53	0.62	24.72
As	wet	0.24	0.02	<0.03	<0.09	0.02	0.14
	dry	0.41	0.04	0.05	0.16	0.04	0.25
Pb	wet	<0.06	<0.20	<0.06	<0.24	<0.06	0.72
	dry	<0.10	<0.34	<0.11	<0.43	<0.13	1.6

Section VI

Miscellaneous Materials

TABLE C-30
Sample Collection
Scheme
Influents and Effluents

Date		Influent	Effluent		Area of
Julian	Gregorian		Pond 1	Pond 2	Dredge Activity
76.4	3-16	X			5, 6
76.5	3-16			X	
79.4	3-19	X			3
79.5	3-19			X	
82.3	3-22	X			3
82.4	3-22			X	
82.5	3-22	X			1, 2
82.7	3-22			X	
83.3	3-23	X			1 (at spill site)
83.4	3-23			X	
92.5	4-1			X	
93 to 98	4-2 to 4-7			X	Solids from high speed centrifugation of 500 l. effluent
94.5	4-3		X	X	
95.5	4-4		X	X	
96.5	4-5			X	
97.5	4-6		X	X	

TABLE C-31. SEDIMENT EXCHANGE FLOW DIAGRAM

SAMPLE

Centrifuge and separate

→ Interstitial water (discard)

RESIDUE

(1) NH_4OAc
(2) Centrifuge and separate

← NH_4OAc EXTRACT (Analyze)

RESIDUE

(1) Wash with deionized water
(2) Centrifuge and separate

→ DEIONIZED WATER WASH (Analyze)

RESIDUE

(1) HOAc
(2) Centrifuge and separate

← HOAc EXTRACT (Analyze)

RESIDUE

(1) Wash with deionized water
(2) Centrifuge and separate

→ DEIONIZED WATER WASH (Analyze)

RESIDUE

(1) $HONH_2$
(2) Centrifuge and separate

← $HONH_2$ EXTRACT (Analyze)

RESIDUE

Left branch:

(1) $H_2O_2 + HNO_3$ digest
(2) $NH_4OAc + HNO_3$
(3) Centrifuge and separate

← $NH_4OAc + HNO_3$ EXTRACT (Analyze)

RESIDUE

HF + fuming HNO_3 digest

DIGESTED SAMPLE (Analyze)

Right branch:

(1) $H_2O_2 + HNO_3$ digest
(2) HNO_3
(3) Centrifuge and separate

→ HNO_3 EXTRACT (Analyze)

RESIDUE

HF + fuming HNO_3 digest

DIGESTED SAMPLE (Analyze)

Appendix D

APPENDIX D

Using "Predredge Analysis of Sediment at Slip 1" data, found in Appendix C, Section I, and formulae "A", "B", and "C" shown below, it is possible to predict the amount of pollutant released from 0.2 l. of sediment via the "Standard Elutriate Test" and "interstitial water monitoring". Also, an estimate of the amount of a pollutant in 0.2 l. of sediment considered for dredging may be made in a similar manner.

(A) Shake Test

Amount of Pollutant Released per 0.2 l. Sediment = (Conc. poll.) ((1 l.)-(0.2 l. X % sol. by Vol))

(B) Interstitial Water

Amount of Pollutant Released per 0.2 l. Sediment = (Conc. poll.) (0.2 l.) (100-% sol. by vol.)

(C) Sediment

Amount of Pollutant in 0.2 l. sediment = (Conc. poll.) (0.2 l.) (Density sed.)

$$\%\ \text{solids by volume} = \frac{\text{volume solid (after centrifugation)}}{\text{Volume sediment (before centrifugation)}}$$

where:

Volume solid (after centrifugation) = difference between volume sediment (before centrifugation) and volume of water obtained from centrifugation of sediment at 9,000 RPM for 20 minutes.

The results of these calculations are found in Tables D-1 through D-5. In order to estimate the total pollutant burden for the dredge sediment or predict the amount of pollutant to be released via the "Standard Elutriate Test" or by "interstitial water monitoring", it is necessary to know the volume of sediments to be dredged. The volumes may be calculated by estimating the area to be dredged within each of six sample areas of Slip 1 (see Figure D-1) and using an estimated dredge depth of one foot. The total dredge volume is found by summing the volumes calculated for each area (see equation D).

(D) $V_{Total} = V_1 + V_2 + V_3 + V_4 + V_5 + V_6$

$V_{Total} = (3,300 + 2,200 + 1,100 + 300 + 1,200 + 1,900)\ yd.^3$

$V_{Total}\quad 10,000\ yd.^3$

The amount of a pollutant to be released during dredging of each area may be predicted using the above volumes along with the amount of pollutant released via each predictive test (see Tables D-1 through D-5) and equation "E". It follows that the total amount of pollutant predicted to be released for the whole dredge operation is given by the sum of amounts predicted to be released from each area.

(E)

$$\text{Amount of pollutant predicted to be released or total pollutant burden of dredge sediments} \quad \left(\frac{\text{Amount of Poll.}}{\text{0.2 l. sed.}}\right) \left(\frac{\text{3.79 l}}{\text{gal}}\right) \left(\frac{\text{202 gal}}{\text{yd.}^3}\right) (\text{Vol. in yd.}^3)$$

The pollutant burden of the dredged sediments for each area and the area taken as a whole is calculated in a similar manner. Results of calculations for pollutant sediment burden and amounts predicted to be released for each predictive test by area are found in Tables D-6, D-7 and D-8.

The amount of each pollutant returning to the river from pond 2 may be estimated using measured pumped volumes of pond 2 water (see Table D-9) and pond 2 effluent data found in Appendix C, Section II. The amount of pollutant present in dredge return water due to river water dredged with Slip 1 sediments was established using pumped volumes of pond 2 water (see Table D-9) and the average pollutant concentration found in the saline river water background site during the dredge (see Appendix C, Section IV). Totals of each pollutant in Tables D-6, D-7 and D-8, along with estimated amounts of each pollutant returning to the river with pond 2 water (both corrected for contribution of each pollutant present in the river water and uncorrected) are summarized in Table 16 found in the body of the text.

Table D-1. RESULTS OF PREDREDGE ANALYSIS SLIP 1 COMPOSITE #1

Metals	Elutriate Test ug/l	Amt. Rel. 200 ml. sed. in ug/0.2 l.	Int. H_2O ug/l	Amt. Rel. 200 ml. sed. in ug/0.2 l.	Sed. wet wt. ug/g	Total in g/0.2 l.
As	16.2	14.1	21.2	1.5	7.8	2.12×10^{-3}
Cd	4.0	3.5	6.0	0.4	0.51	1.39×10^{-4}
Cr	45	39.2	15	1.1	21	5.71×10^{-3}
Cu	6.0	5.2	6.0	0.42	39.0	1.06×10^{-2}
Fe	560	488	4,000	283	25,100	6.8
Pb					44	1.2×10^{-2}
Mn	2,880	2,508	1,640	116	250	6.8×10^{-2}
Hg	0.1	0.09	0.4	0.03	0.1	2.7×10^{-5}
Ni	<10	<8.7	<10	<0.71	15	4.1×10^{-3}
Zn	12.	10.4	38.	2.7	110	3.0×10^{-2}
PCB	158	138	1,700	120	72	2.0×10^{-2}
Oil/Grease	$1.9 \times 10^{+3}$	$1.7 \times 10^{+3}$	-	-	715	1.9×10^{-1}
Total P	$0.11 \times 10^{+3}$U	$0.10 \times 10^{+3}$U	$3.320 \times 10^{+3}$U 1.8F	$.2350 \times 10^{+3}$U .13F	590	1.6×10^{-1}
$N\text{-}NH_3$	$3.3 \times 10^{+3}$	$2.9 \times 10^{+3}$	$9. \times 10^{+3}$	$.64 \times 10^{+3}$	14	3.8×10^{-3}
TKN	4.5×10^{3}	3.9×10^{3}	12×10^{3}	0.85×10^{3}	630	1.7×10^{-1}
COD	360	313	490	34.7	28,200	7.67

U - unfiltered
F - filtered

Density = 1.36 g/ml.
% Solids by volume = 64.62%

Table D-2. RESULTS OF PREDREDGE ANALYSIS SLIP 1 COMPOSITE #2

etals	Elutriate Test ug/l	Amt. Rel. 200 ml. sed. in ug/0.2 l.	Int. H_2O ug/l	Amt. Rel. 200 ml. sed. in ug/0.2 l.	Sed wet wt. ug/g	Total in g/0.2 l.'s
s	12.2	10.7	32.3	2.60	7.3	1.9×10^{-3}
d	8.0	7.0	4.0	0.3	1.36	3.59×10^{-4}
r	43	38	34	2.7	37	9.8×10^{-3}
u	7.2	6.3	7.2	.58	42.2	1.11×10^{-2}
e	300	264	410	33.0	21,800	5.8
b					235	6.20×10^{-2}
n	1,320	1,162	1,920	154.8	245	6.47×10^{-2}
g	0.1	0.09	0.1	0.008	0.1	2.64×10^{-5}
i	<10	<8.8	<10	<0.8	15	4.0×10^{-3}
n	20	18	<10	<0.8	310	8.20×10^{-2}
:B	29	26	143	11.5	7.7	2.03×10^{-3}
il/Grease	7.6×10^3	6.7×10^3	-	-	737	2.0×10^{-1}
otal P	.80U $.39 \times 10^3$F	.70U $.34 \times 10^3$F	4.50U 1.76×10^3F	0.36U 0.142×10^3F	530	1.4×10^{-1}
$-NH_3$	3.8×10^3	3.3×10^3	11.0×10^3	$.89 \times 10^3$	17	4.5×10^{-3}
<N	5.8×10^3	5.1×10^3	17×10^3	1.4×10^3	690	1.8×10^{-1}
)D	360	317	380	30.6	28,400	7.69

- unfiltered
- filtered

Density = 1.32 g/ml.
% Solids by volume = 59.70%

Table D-3. RESULTS OF PREDREDGE ANALYSIS SLIP 1 COMPOSITE #3 & 4

Metals	Elutriate Test ug/l	Amt. Rel. 200 ml. sed. in ug/0.2 l.	Int. H_2O ug/l	Amt. Rel. 200 ml. sed. in ug/0.2 l.	Sed. wet wt. ug/g	Total in g/0.2 l.
As	15.9	14.3	21.5	2.12	7.6	2.07 X 10^{-}[illegible]
Cd	4.0	3.6	4.	0.4	4.95	1.35 X 10^{-}[illegible]
Cr	43	39	43	4.2	20	5.4 X 10^{-3}
Cu	3.6	3.2	4.8	0.47	58.7	1.60 X 10^{-}[illegible]
Fe	240	216	200	19.7	21,000	5.71
Pb					84	2.3 X 10^{-2}
Mn	224	201	220	21.7	224	6.09 X 10^{-}[illegible]
Hg	0.2	0.18	0.3	0.03	0.1	2.7 X 10^{-5}
Ni	$<$10	$<$ 9.0	$<$10	$<$0.98	22	6.0 X 10^{-3}
Zn	$<$2	$<$1.8	$<$2	$<$0.2	1,000	2.7 X 10^{-1}
PCB	30	27	147	14.5	2.3	6.3 X 10^{-4}
Oil/Grease	13 X 10^3	12 X 10^3	-	-	1,120	3.0 X 10^{-1}
Total P	0.81U 0.52 X 10^3F	0.73U 0.45 X 10^3F	2.84U 1.36 X 10^3F	0.280U 0.134 X 10^3F	520	1.4 X 10^{-1}
$N-NH_3$	2.6 X 10^3	2.3 X 10^3	6.2 X 10^3	0.61 X 10^3	15	4.1 X 10^{-3}
TKN	4.8 X 10^3	4.3 X 10^3	16 X 10^3	1.6 X 10^3	460	1.3 X 10^{-1}
COD	263	236	260	25.6	28,700	7.81

U = unfiltered
F = filtered

Density = 1.36 g/ml.
% solids = 50.77

Table D-4. RESULTS OF PREDREDGE ANALYSIS SLIP 1 COMPOSITE #5

Metals	Elutriate Test ug/l	Amt. Rel. 200 ml. sed. in ug/0.2 l.	Int. H_2O ug/l	Amt. Rel. 200 ml. sed. in ug/0.2 l.	Sed. wet wt. ug/g	Total in g/0.2 l.
As	6.9	6.1	20.4	1.74	5.3	1.44×10^{-3}
Cd	4.0	3.5	6.0	0.5	2.83	7.70×10^{-4}
Cr	47	42	44	3.8	22	6.0×10^{-3}
Cu	18	1.6	9.6	0.82	51.7	1.40×10^{-2}
Fe	260	230	8,400	716	24,500	6.66
Pb					67	1.8×10^{-2}
Mn	1,920	1,700	5,280	450	240	6.52×10^{-2}
Hg	0.6	0.5	1.0	0.09	0.1	2.7×10^{-5}
Ni	<10	<8.9	<10	<0.9	10	2.7×10^{-3}
Zn	8.0	7.1	74	6.31	610	1.65×10^{-1}
CB	13	12	85	7.2	0.82	2.23×10^{-4}
il/Grease	3.0×10^3	2.7×10^3	-	-	700	1.9×10^{-1}
otal P	.24U $.19 \times 10^3$F	0.21U 0.17×10^3F	3.94U 0.26×10^3F	0.336U 0.02×10^3F	540	1.5×10^{-1}
-NH_3	2.2×10^3	1.9×10^3	5.5×10^3	0.47×10^3	23	6.3×10^{-3}
KN	3.0×10^3	2.7×10^3	12×10^3	1.02×10^3	580	1.6×10^{-1}
OD	270	239	430	36.7	20,900	5.68

= unfiltered Density = 1.36 g/ml.
= filtered % Solids = 57.38

Table D-5. RESULTS OF PREDREDGE ANALYSIS SLIP 1 COMPOSITE #6

Metals	Elutriate Test ug/l	Amt. Rel. 200 ml sed. in ug/0.2 l.	Int. H_2O ug/l	Amt. Rel. 200 ml. sed. in ug/0.2 l.	Sed. wet wt. ug/g	Total in g/0.2 l.
As	11.7	10.5	26.5	2.48	6.4	1.74×10^{-3}
Cd	4	3.6	4	0.37	0.57	1.55×10^{-4}
Cr	47	42	48	4.5	15	4.1×10^{-3}
Cu	9.0	8.0	9.0	0.8	31.5	8.57×10^{-3}
Fe	540	483	40,000	3,750	18,300	4.98
Pb					440	1.20×10^{-1}
Mn	3,360	3,003	9,760	906	183	4.98×10^{-2}
Hg	0.1	0.09	0.1	0.009	<0.1	2.7×10^{-5}
Ni	<10	<8.9	<10	<0.9	<10	$<2.7 \times 10^{-3}$
Zn	4.	3.6	10.	0.9	120	3.3×10^{-2}
PCB	8	7.1	51	4.8	1.0	2.72×10^{-4}
Oil/Grease	1.2×10^3	1.1×10^3	-	-	361	9.8×10^{-2}
Total P	.12U $.065 \times 10^3$F	.11U 0.058×10^3F	1.36U .20F	0.127U 0.02×10^3F	510	1.4×10^{-1}
$N\text{-}NH_3$	3.0×10^3	2.7×10^3	8.2×10^3	$.77 \times 10^3$	69	1.9×10^{-2}
TKN	5.0×10^3	4.5×10^3	12×10^3	1.1×10^3	480	1.3×10^{-1}
COD	<250	<223	340	31.8	26,200	7.13

U = unfiltered
F = filtered

Density = 1.36 g/ml.
% Solids = 53.13%

Table D-6. AMOUNT OF POLLUTANT PRESENT IN DREDGE SEDIMENTS*

Area	1	2	3 & 4	5	6	Total
As	26,700	16,000	11,000	6,600	12,600	72,900
Cd	1,750	3,000	7,200	3,500	1,100	16,550
Cr	72,000	83,000	29,000	28,000	30,000	242,000
Cu	134,000	93,000	86,000	64,000	62,000	439,000
Fe	86,000,000	49,000,000	31,000,000	31,000,000	36,000,000	233,000,000
Pb	151,000	522,000	123,000	83,000	870,000	1,749,000
Mn	860,000	545,000	326,000	300,000	362,000	2,393,000
Hg	340	220	145	125	200	1,030
Ni	52,000	34,000	32,000	12,000	20,000	150,000
Zn	380,000	690,000	1,242,000	760,000	240,000	3,312,000
PCB	252,000	17,000	3,400	1,000	2,000	275,400
Oil & Grease	2,394,000	1,684,000	1,600,000	874,000	712,000	7,264,000
Total P	2,016,000	1,180,000	750,000	690,000	1,020,000	5,656,000
$N-NH_3$	48,000	38,000	22,000	29,000	138,000	275,000
TKN	2,142,000	1,520,000	700,000	740,000	950,000	6,052,000
COD	97,000,000	65,000,000	42,000,000	26,000,000	52,000,000	282,000,000

* Results expressed in grams

Table D-7. PREDICTED RELEASE BY ELUTRIATE TEST*

Area	1	2	3 & 4	5	6	Total
As	178	90	77	28	76	449
Cd	44	59	19	16	26	164
Cr	494	320	210	195	305	1,524
Cu	66	53	17	7	58	201
Fe	6,150	2,220	1,160	1,060	3,510	14,100
Pb	5,050	2,960	2,165	1,795	1,690	13,660
Mn	31,600	9,800	1,080	7,820	21,800	72,100
Hg	1.1	0.8	1.0	2.3	0.7	5.9
Ni	110	75	48	41	65	110
Zn	131	152	10	33	26	309
PCB	1,740	220	145	55	52	2,212
Oil/Grease	21,420	56,400	64,300	12,400	8,000	162,520
Total P	U 2,500	U 5,900	U 3,900	U 970	U 800	14,070
	F 1,260	F 2,900	F 2,500	F 780	F 420	7,860
N-NH_3	37,000	28,800	12,300	8,740	19,600	106,440
TKN	49,000	43,000	23,000	12,400	32,700	160,100
COD	3,940	2,670	1,265	1,100	1,620	8,975

* Results expressed in grams

U = unfiltered
F = filtered

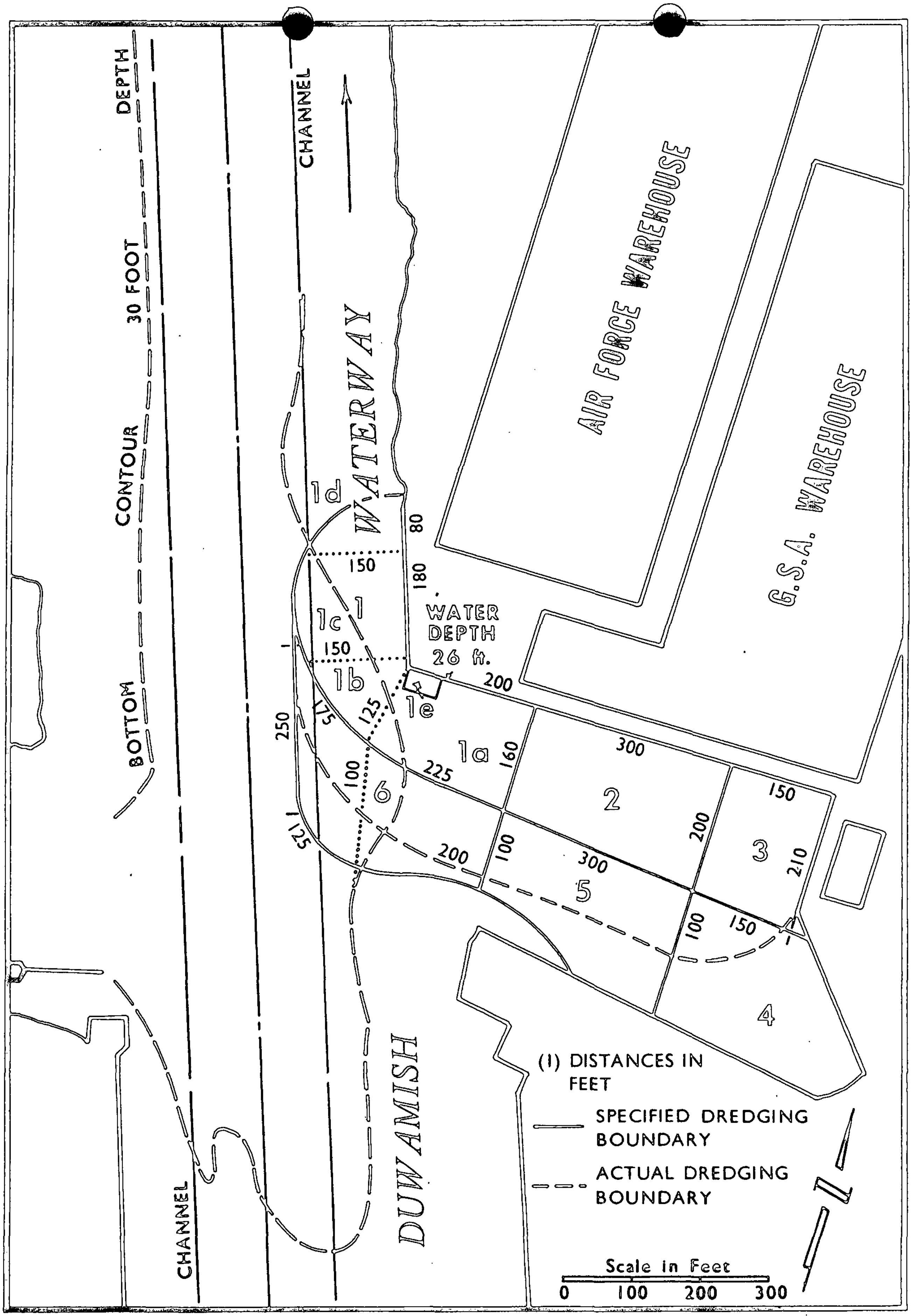
Table D-8. PREDICTED RELEASE BY INTERSTITIAL WATER MONITORING*

Area	1	2	3 & 4	5	6	Total
As	19	22	11	8	18	78
Cd	5	2.5	2.1	2.3	2.7	14.6
Cr	14	23	23	17	33	110
Cu	5.3	4.9	2.5	3.8	5.8	22.3
Fe	3,570	280	100	3,300	27,300	34,550
Pb	360	190	140	170	250	1,110
Mn	1,460	1,300	120	2,100	6,600	11,580
Hg	0.4	0.1	.2	.4	0.1	1.2
Ni	9	7	5	4	7	9
Zn	34	7	1	29	7	70
PCB	1,510	97	78	33	35	1,753
Oil/Grease	-	-	-	-	-	-
Total P	U2,960	U3,030	U1,500	U1,550	U920	9,960
	F1,640	F1,200	F720	F90	F145	3,795
N-NH_3	8,060	7,500	3,270	2,160	5,600	26,590
TKN	10,700	12,000	8,600	4,690	8,000	43,990
COD	440	260	140	170	230	1,240

* Results expressed in grams
U Unfiltered
F Filtered

Table D-9. FLOW VOLUMES OUT OF POND 2 VS DATE

Sample	Date		Gallons
12503	3-16-75		481,000
12611	3-19-76		239,000
12617	3-22-76		
13626	3-22-76		981,000
13636	3-23-76		543,000
14604	4-1-76		4,788,000
15610	4-3-76		1,488,000
15616	4-4-76		378,000
15620	4-5-76		
15625	4-6-76		936,000
		Total	9,834,000



OVERVIEW OF COMPOSITE SAMPLING AREAS AT SLIP 1

FIGURE D-1

Appendix E

was calculated using the results of the land survey taken after the spoils were allowed to stand and dewater.

The total PCB burden (PCB total) can be expressed as a function of PCB concentration and pond 1 volume in the following manner. The amount of PCB in the individual areas is calculated using the PCB concentrations for each area and volumes of each area. The total PCB burden is then obtained by summing the amounts of PCB calculated for each area.

$$\text{PCB Total} = (\text{PCB})_1 V_1 + (\text{PCB})_2 V_2 + (\text{PCB})_3 V_3$$

$$(\text{PCB})_1 V_1 = \left(\frac{145 \times 10^{-6} \text{ lb. PCB}}{\text{lb. sed.}}\right)\left(\frac{1 \text{ gallon PCB}}{11.5 \text{ lb. PCB}}\right)\left(\frac{90 \text{ lb. sed.}}{\text{ft.}^3 \text{ sed.}}\right)(142{,}500 \text{ ft.}^3)$$

$$(\text{PCB})_1 V_1 = 160 \text{ gallons}$$

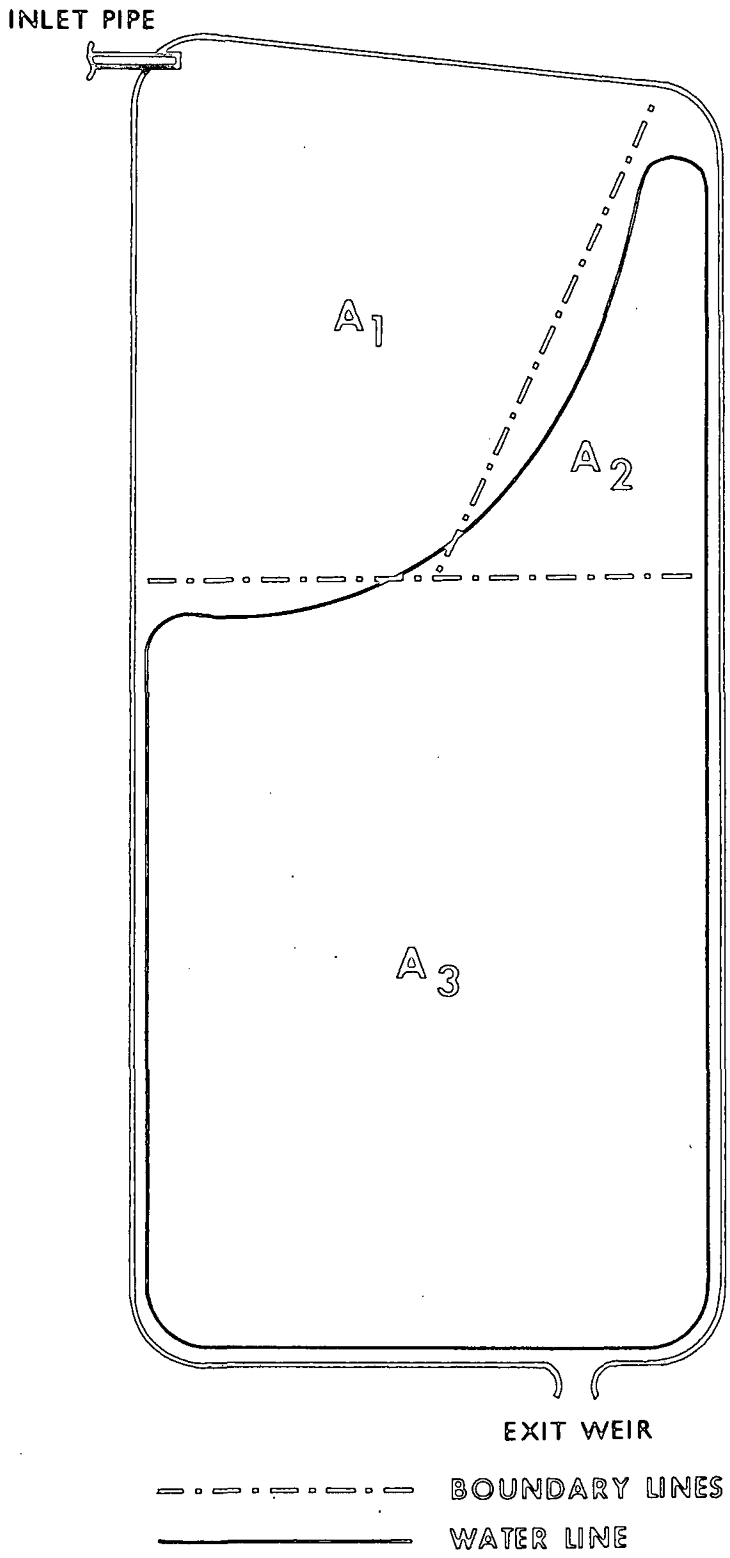
$$(\text{PCB})_2 V_2 + (\text{PCB})_3 V_3 = \left(\frac{30 \times 10^{-6} \text{ lb. PCB}}{\text{lb. sed.}}\right)\left(\frac{1 \text{ gal. PCB}}{11.5 \text{ lb PCB}}\right)\left(\frac{90 \text{ lb. sed.}}{\text{ft.}^3 \text{ sed.}}\right)(50{,}700 \text{ ft}^3)$$

$$(\text{PCB})_2 V_2 + (\text{PCB})_3 V_3 = 10 \text{ gallons}$$

$$(\text{PCB}) \text{ Total} = 160 + 10 = 170 \text{ gallons}$$

The total amount of PCB found in pond 1 by this method is estimated to be 170 gallons.

FIGURE E-1



AREAS OF HOLDING POND USED
TO CALCULATE VOLUME OF DREDGE SPOILS

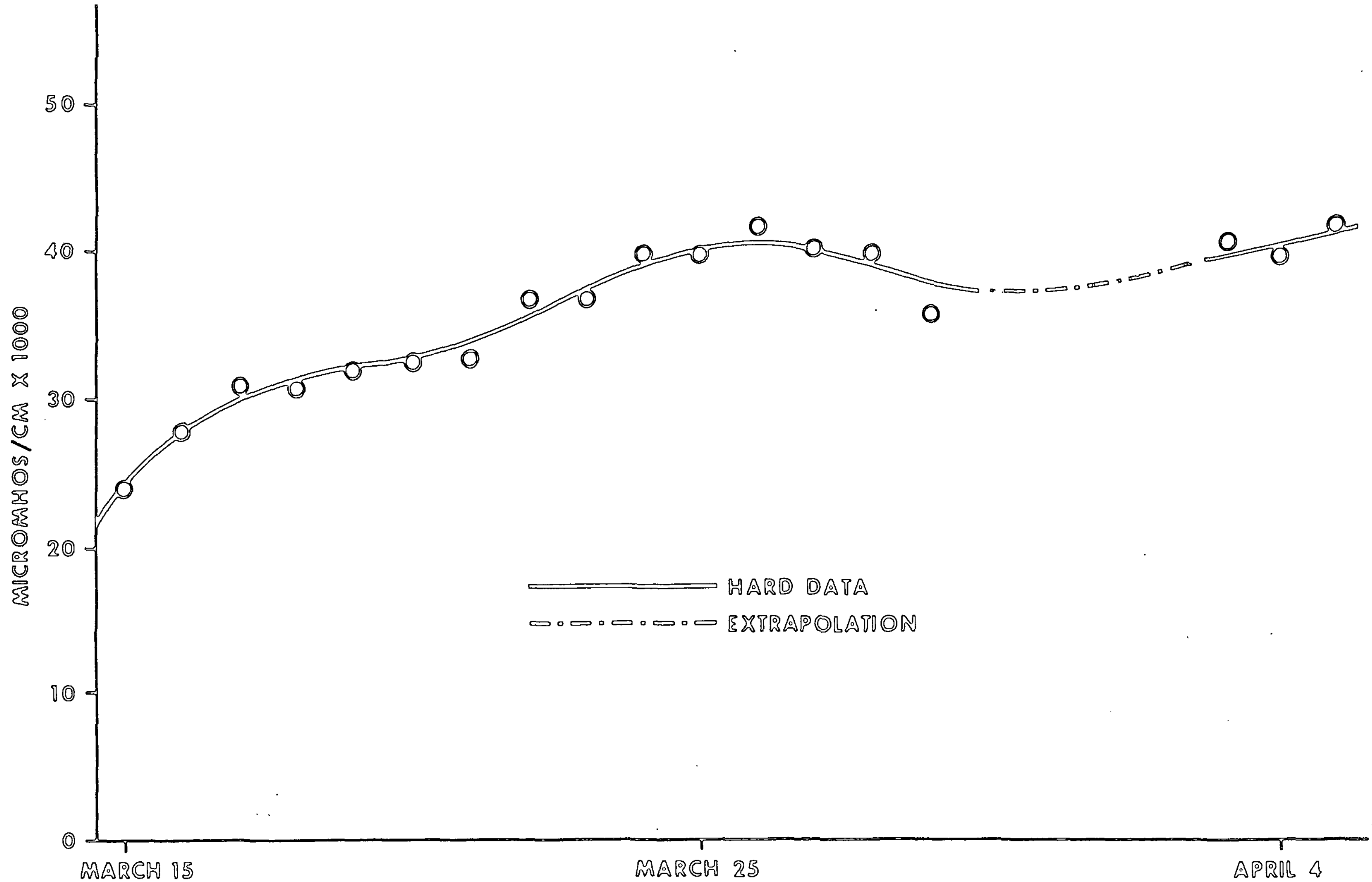
Appendix F

Appendix F

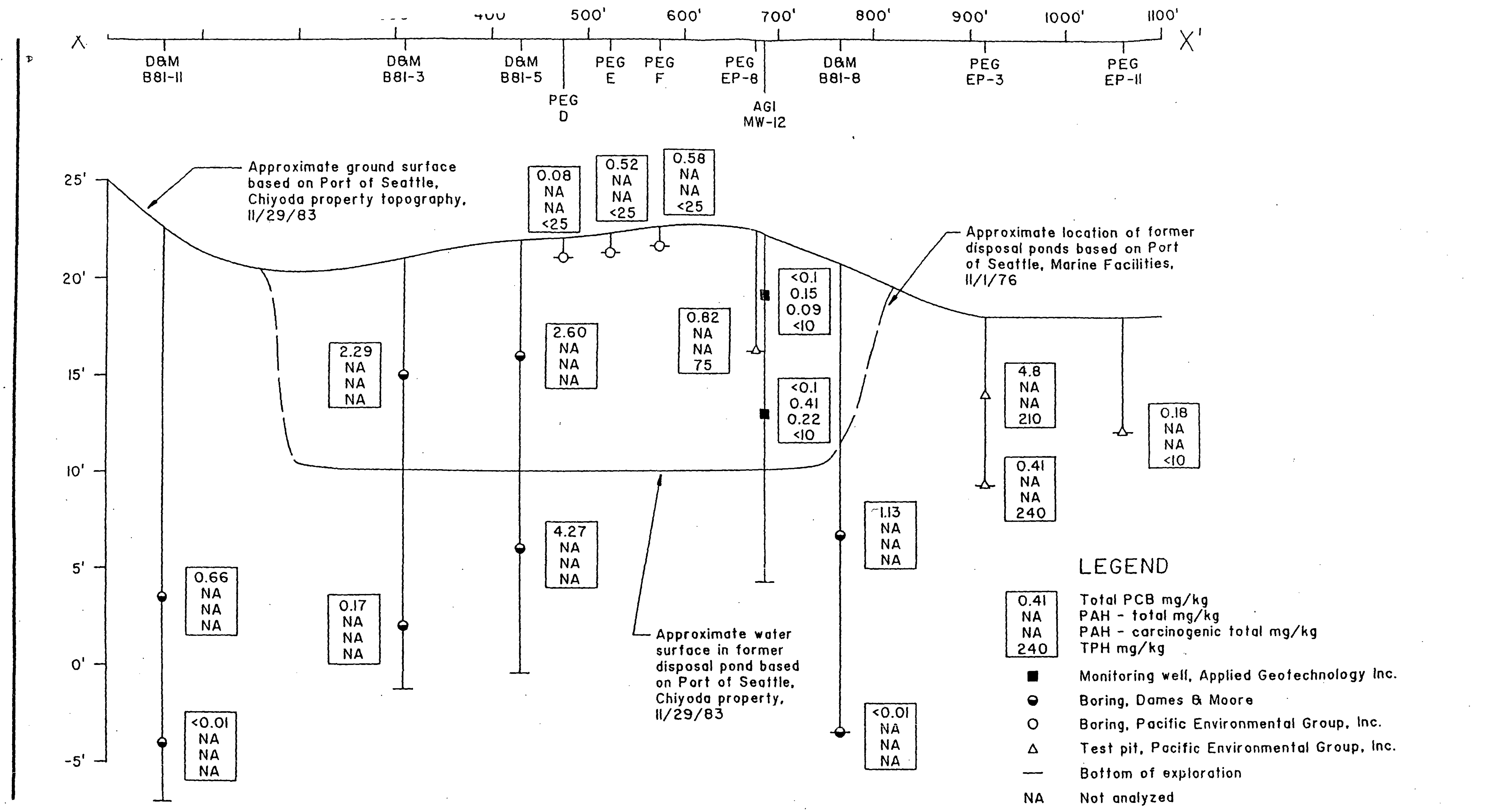
HydroLab Results

Water quality parameters temperature, dissolved oxygen (DO), pH and conductivity of Pond 2 effluent were monitored continuously during the dredge operation. Daily averages of each are plotted versus Julian date in Figures F-1 and F-2. Temperature, DO, pH and conductivity are expressed in ^{o}C, ppm, standard pH units and micromhos respectively. Even though the instrument was calibrated daily, occasional instrument problems necessitated deletion of some data.

FIGURE F-1



CONDUCTIVITY-EFFLUENT POND 2



1" = 100' Horizontal Scale
1" = 5' Vertical Scale

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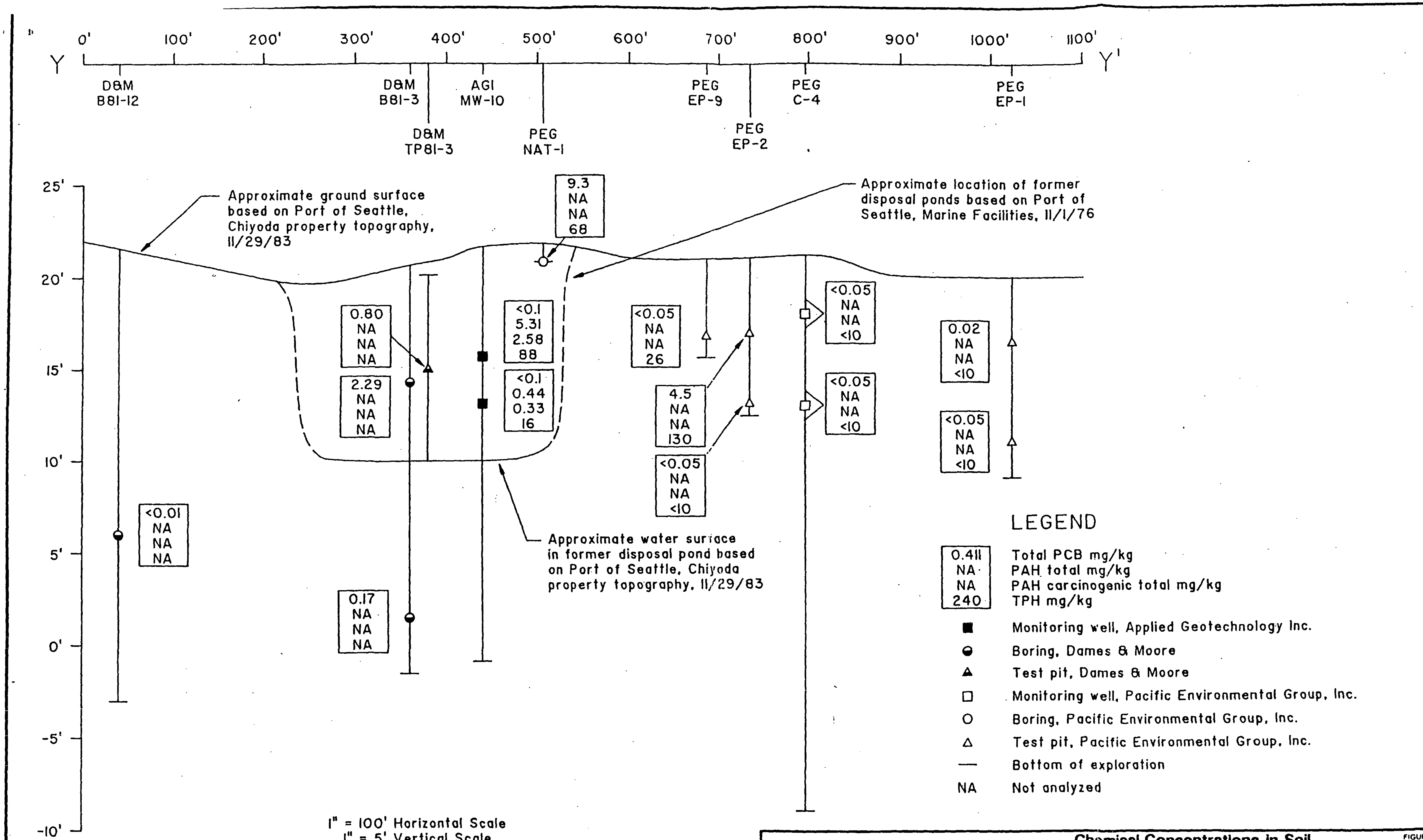
Chemical Concentrations in Soil
Cross Section X - X'
Chevron/Site 64534097
Seattle, Washington

FIGURE **6**

JOB NUMBER	DRAWN	APPROVED	DATE	REVISED	DATE
15,582.022	JFL	GCC	10 Aug 92		



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Geotechnical Engineering
Geology & Hydrogeology

Chemical Concentrations in Soil
Cross Section Y - Y'
Chevron/Site 64534097
Seattle, Washington

FIGURE **7**

JOB NUMBER	DRAWN	APPROVED	DATE	REVISED	DATE
15,582.022	JFL	GCC	10 Aug 92		